NFAC No. 4432/78

11 October 1978

MEMORANDUM FOR: See Distribution

FROM : Coordinator for Academic Relations, NFAC

SUBJECT : DCI Discussion/Dinner on Soviet Science and Technology Lags, Wednesday, 18 October 1978

1. On Admiral Turner's behalf you are invited to participate in a Discussion/Dinner in his Conference Room on Wednesday, 18 October. Our subject will be the paradox that despite its massive and continuing investment in science and technology, the Soviet Union lags behind the West in general and the United States in particular in nearly all S&T areas. This is true, despite the fact that Soviet performance is relatively better in the military than in the civilian sector. [redacted] 25X1
will open the discussion by directing attention to several specific questions that might be addressed.

2. Five senior specialists have been invited from outside. They are:

Dr. Robert R. Fossum, Director
Defense Advanced Research Projects Agency

Dr. H. Guyford Stever, former President's Science Advisor and former Chairman US-USSR Joint Commission on Science and Technology (JCS&T)

Dr. Herbert Fusfeld, current member US-USSR JCS&T, professor at New York University.

Dr. Betsy Anker-Johnson, Associate Director, Argonne National Laboratories and former member US-USSR JCS&T.

Dr. Charles M. Huggins, Manager, International Programs, Corporate Research & Development, General Electric Company.

3. The plan for the evening is as follows: The company will assemble in the DCI Conference Room between 5:30 and 6:00. Refreshments will be served. The discussion will begin at 6:00 and continue until 7:00 when

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dinner will be served. After dinner, the discussion will be resumed and will continue until approximately 9:00.

4. For those of you who do not consider yourselves familiar with the background, two chapters from the book that John Thomas and Ursula Kruse-Vaucienne edited for the National Science Foundation, Soviet Science and Technology: Domestic and Foreign Perspectives, 1977, are attached. If you are unable to attend, please call [redacted] 25X1

STAT

[redacted]

Attachments

Distribution:
Mr. Carlucci
Mr. Robert R. Bowie
Dr. Sayre Stevens
Mr. Leslie Dirks
25X1 [redacted]
STAT [redacted]
25X1 [redacted]

invited to the dinner
CB

SOVIET SCIENCE AND TECHNOLOGY:

DOMESTIC AND FOREIGN PERSPECTIVES

Edited by

[redacted]

and

[redacted]

Based on a workshop held at Airlie House, Virginia
on November 18-21, 1976

Chairman and Organizer
John R. Thomas

Published for the National Science Foundation by
The George Washington University
Washington, D.C.

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TOWARD UNDERSTANDING SOVIET SCIENCE AND TECHNOLOGY: AN OVERVIEW

I. Objectives and Approach

A. Intent

Using the papers in this volume as a basis, this overview summarizes principal issues in the science-technology relationship between the U.S. and the U.S.S.R., clarifies perspectives which are fundamental to establishing viable ties, and develops guidelines which should be useful in future interactions. Non-specialists in Soviet scientific affairs from either U.S. industry concerned with commercial interactions with the Soviets or government concerned with formulating and implementing policies or programs with the U.S.S.R. should find this overview a useful introduction to this volume

While ideas from the papers herein are cited to illustrate points in this overview, it is not a complete review. Rather, we have assumed an interpretive responsibility for identifying principal issues, for selecting illustrative examples, and for choosing a framework which emphasizes perspectives and guidelines which we believe to be useful.

B. Major Themes

The discussion in this volume clearly shows that an understanding of science in any country, and particularly in the U.S.S.R., cannot result from a study of science alone. This would yield a narrow, sterile view; rather, science should be examined as one of several major components in a socially dynamic system. Such an approach will tell us more about both the science and the system.

For a better understanding of Soviet science and technology and their interaction within the system and with the West, we have organized the major ideas developed at the workshop into three thematic parts: perceptions, structure and weaknesses, and opportunities and obstacles.

In Section II on perceptions, we consider how U.S. and Soviet perceptions of each other substantially influence their respective perspectives and actions. The extent to which we can appreciate these perceptions improves our capacity to interpret developments and to extrapolate trends, thus minimizing difficulties already inherent in analyzing Soviet affairs.

Section III on the structure and weaknesses of Soviet science provides the context for assessing how cultural patterns both account for developments to date and future trends, and diminish the effectiveness of Soviet science.

In Section IV on U.S.-U.S.S.R. interactions in science and technology, we consider these tactically as a barter paradigm in which the needs of each side and the ease of potential transactions are assessed. We identify factors which either promote and facilitate transactions or which impede them.

Common threads identified in this volume are repeated as they aid in understanding the separate themes of this overview: perceptions, structure and weaknesses, opportunities, and obstacles. These common threads — such as the complex relationship of the Party to Soviet science, the inefficient integration of science with technology and into production, the historical mandate of science, and the preemption of resources by the military — are repeated deliberately as they take on new dimensions or substantiate the themes in sections II, III, and IV. Weaving these threads throughout the overview also helps to develop an integrated view of scientific and political components

C. Views of Science and Technology

The term "science," used until now as a convenient shorthand, is imprecise. The workshop addressed issues related to basic and applied science, and technology and its conversion to useful practice in the U.S.S.R. Since this broad spectrum of Soviet science and technology then interacts with the economy, the Party, the military, industry and the West, perhaps a term like "scientific-technological fabric" might be more appropriate, but it seems too awkward. We use "science" in this overview to refer in general to the spectrum from basic science to applied technology, but we specify narrower meanings when appropriate. The present vernacular seems to permit such a shorthand.

The use of "science" as a term which embraces both science and technology is also warranted since this workshop was organized to examine the interaction between the institutions of Soviet science and other components of the Soviet system rather than to assess individual disciplines. However, we do take note, as appropriate, of specific areas of science for illustrative purposes. For example, Adams* traces the political development of biology during the Lysenko affair to demonstrate the survival instinct of the Academy; Humphrey discusses developments in single cell protein production to show that vertical integration of Soviet science with large-scale production can be accomplished in the civilian sector, comparable to the process in the military area depicted in part by Holloway.

Ganley, who chaired the final session of the workshop, stated that reducing tensions between the U.S. and U.S.S.R. is a principal objective of U.S. foreign policy. Both countries seek avenues of interaction which are mutually beneficial and least contentious. Science offers such an opportunity. The acknowledged universality of science also avoids the impediments of proprietary commercial trade. Science strengthens

*All names used in this paper without further identification refer to authors of papers in this volume or to participants in the workshop discussions.

opportunities for mutual national growth, provides broad avenues for communication, and offers situations for applying the principles of equality, reciprocity and mutual benefit which are required by all U.S.-U.S.S.R. agreements in the science and technology areas. In addition to the objective benefits of scientific cooperation and the accompanying progressive interdependence, members of the scientific community are generally articulate. Therefore, the results of constructive interaction in science can be expected to find their way into the social context of each country through dialogues in the classroom and research laboratory, and through published material.

But such cooperation frequently raises questions on both sides, particularly in the U.S.S.R., as to whether comparatively unrestrained interaction in science may not jeopardize national security, compromise ideology, or impair commercial integrity. For example, to quote Parrott:

> Who [in the U.S.S.R.] is likely to resist the expansion of Western ties? The regime's ideological officials appear to dislike the idea. These officials are charged with protecting the doctrine of the U.S.S.R.'s scientific and economic superiority over capitalism, and heavy reliance on Western technology would make this claim more difficult to defend.

So, even an apparently mutually beneficial program of cooperation confined to basic science contributes to political apprehension. Despite such negative factors, both countries seem to believe that positive results from active cooperation in science outweigh possible losses; this sanguine view is implicit in the papers in this volume. Few, if any, participants advocate a diminution of U.S.-U.S.S.R. interactions; rather, they suggest that uncertainties should be carefully considered and political and economic realities taken into account in order to prevent unrealistic expectations from interaction with the Soviets.

A quest to advance an understanding of Soviet science provokes a question of "What for?" Certainly, an essential objective of such a quest is to create a basis for extrapolating future gains, e.g., to what extent can interactions in science reduce political tensions, what scientific success can be expected from bilateral cooperation, and what fruit will be borne by expanded commercial ventures? But, as in any science, useful extrapolations depend heavily upon valid, quantitative models. Because of lack of data, current Western models of Soviet science and the economy exist mainly in terms of what can be described as perceptions by the proverbial five blind men or by a related understanding of the Soviet psyche which we may deduce from cultural and historical evidence. (The workshop did not deal with the latter question.) Thus, predicting trends in the U.S.S.R. is uncertain and we should explicitly acknowledge this difficulty. Nevertheless, we have accumulated substantial non-quantitative information about the Soviet Union, particularly about its science. And the science area is a direct link to an understanding of other aspects of the Soviet system of interest to us, e.g., economics, politics, and defense.

Science can also be utilized as an item of exchange in diplomatic and commercial intercourse. It can provide an avenue for reducing differences and for achieving common objectives. This applies particularly to U.S.-Soviet relationships. Parrott examines Soviet receptivity to Western know-how and finds mixed views:

> Since about 1972 the Soviet leadership has judged the prospective benefits to outweigh the anticipated costs, and it has sought greatly increased trade and technical ties with the West. Just how firm the support for this new policy is within the leadership is very difficult to say. A preliminary survey of the speeches of prominent Politburo members shows no evidence of overt opposition to the change. There is, though, a noticeable difference between Brezhnev's vigorous endorsements of "long-term, large-scale economic cooperation" and Suslov's rather neutral allusions to the new policy.

While Parrott's discussion refers to technology, it is also relevant to basic science. Despite possible reservations by some Soviet leaders, large-scale Soviet efforts to date to obtain Western technology and pick Western scientific brains are the best indicators of Soviet intentions.

The pressure on both sides to improve the quality and extent of their interaction can be viewed as a part of the increasing international interdependence and global concerns over food, health, energy, resources, communications, and weather. As these imperatives encourage more frequent and intense interactions, the existing tensions are likely to be reduced.

II. <u>Perceptions and Their Influence</u>

A. Significance of Perceptions

Initiatives and responses by the U.S. and U.S.S.R. depend on how each country perceives the other and how each perceives itself. This concept is essential and will be useful to the Western reader involved in communicating with the U.S.S.R. Because only limited reliable information about the U.S.S.R. is available and because even this is distorted by substantial political and cultural differences, we are forced to act on our perceptions of Soviet reality. Thus, action derives from perception.

An examination of how the U.S. and the U.S.S.R. perceive each other and assess their respective internal strengths and weaknesses provides a useful guide to effective action. From contributed papers, we have identified seven explicit elements in U.S. perceptions of the U.S.S.R. Since the workshop did not deal with U.S. self-perceptions, these are not considered in this overview. We also identified seven elements of Soviet self-perception and two elements of Soviet perception of the U.S.

We do not presume that our classifications are complete or independent of each other. But we do believe that exploring these perceptions will contribute to improving our understanding of U.S.-Soviet interactions.

B. U.S. Perceptions of the U.S.S.R.

First and most important, we must learn to accept the Soviets and their system as they are rather than as we believe them to be or would like them to become. We must not see a Soviet announcement of a new incentive system or a decentralization measure as signs of a trend towards capitalism, or words by a vocal Soviet dissident as precursors of imminent revolt. Both conclusions are fallacious, but some in the West have so far been unable — or unwilling — to recognize that despite developments such as those noted above, the Soviets are unlikely to change their system radically. The cultural and political roots which spawned the system are too deeply entrenched for such a change. The Soviet psyche seems pre-disposed to seeking and accepting societal arrangements which spread risks, repeat long-established behavior patterns, and militate against basic alterations. Even if the ideology undergoes a basic change, the bureaucratic juggernaut, which traces its origin far back into Russia's history, would no doubt continue its sway. Such a conclusion may seem unnecessarily pessimistic. Yet, accepting the Soviet Union as it is, i.e., as a system shaped by continuing forces such as Russian nationalism and tradition, is the first step to clarifying and improving the sensitivity of our perceptions. Thus, as a first step in developing a pragmatic view of U.S.S.R. technology, Amann suggests:

> An assumption which pervades much Western writing on the subject is that Soviet problems are deeply rooted, systemic, and almost incapable of solution short of major political and economic reform. To date, there has been no serious attempt to evaluate how far Soviet technological performance in particular sectors can be explained by systemic weaknesses and how far by historical backwardness and deliberate (though, perhaps, misguided) policies and priorities.

From Holliday's summary of the discussion, we note a word of caution about superimposing the generally negative Western view of government intrusion in societal activities on the Soviet structure:

> In contrast, another discussant found fault with the typology [of Soviet science] because it tends to project our [Western intellectual] values on Soviet scientists. It is fallacious, he warned, to assume that Soviet scientists relate to political authorities the same way their American counterparts do. He noted, for example, that American intellectuals tend to believe that the less political interference they encounter, the better. Soviet intellectuals, on the other hand, tend to believe that some degree of independence and room for maneuver is good, but that "a lot is a disaster."

Similarly, Gustafson, in cautioning against applying Western desiderata to analyzing the Soviet system, notes that the Soviets consider the certainty of full employment, even if undynamic and involving under-employment in reality, is on balance preferable to the dynamic but unpredictable boom and bust cycles associated with the capitalist system. Lubrano reminds us that we must judge statistics on Soviet science within the Soviet context.

Second, the serious lack of adequate and credible statistical information emerging from the Soviet system adds to our misperceptions. One reason for this seems to be conscious errors in presenting data. Thus, Parrott says that pressure for performance leads to falsifying information: "One source of the difficulty is the widespread inclination of specialized subordinates to falsify the information about economic capacities and reserves on which the leadership must base its efforts to evoke high performance." There is always the possibility that the Soviet administration does not wish to release certain categories of statistics or that their political decisions prevent the collection of particular data. Further, there are some indications that the Soviets may lack certain capability in methodology or the technical facilities for producing the data. Probably the most significant deficiency in information available at home or abroad concerns the Soviet military. Holloway suggests the implications of such an information gap:

> A proper understanding of Soviet science and technology and their relationship to the military requires an examination of the Soviet military research and development effort. This effort absorbs a large part of the resources devoted to R&D in the Soviet Union. It is, unfortunately, difficult to establish precisely how large the proportion is: estimates range from 40 to 80 percent. Whatever the true figure may be, our picture of Soviet science and technology will be seriously lacking if such a large part of it is left uncharted.

To emphasize the inadequacy of Soviet data, Western analysts note that published figures for production are often the goals and not the actual results.

Third, pervasiveness and rigidity of the Soviet bureaucracy characterizes many spheres of Soviet life. The Soviet society seems organically committed to stabilizing its bureaucracy. Not only is the Soviet government itself a huge bureaucracy, but it is overseen by two other large bureaucracies: the Party and the Secret Police (KGB). The bureaucratic phenomenon also afflicts other groups, e.g., the Soviet Academy of Sciences itself operates in a highly bureaucratic fashion. Consequently, any perspective which does not recognize the Soviet bureaucracy and its stifling effect on the system will miss the reality of the Soviet life. Labedz speculates on the potential effect of the bureaucracies on each other:

> ... it is unlikely that apparatchiki will be replaced in the near future by technocrats in the Soviet political structure because of the effect of necessities imposed by science and technology on the Soviet system. It is arguable, however, that technocratic and "rationalistic" attitudes may slowly penetrate the mentality of the apparatchiki. Whether and to what extent this may happen is a question on an altogether different time scale.

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Despite such "domestication" Gustafson notes the high quality of individual Soviet scientists even as he points to the stifling effect of bureaucracy:

> This is not due to any inferiority in the individual abilities of the Soviet scientists (visiting Americans rate them highly), but to the relative rigidity and inefficiency of their policies and organizational structures for science, which hinder the Soviets in responding to the rapid conceptual and methodological changes taking place in many disciplines.

The Soviets are aware of the hobbling effects of their bureaucracy and are developing schemes for improving its effectiveness in guiding Soviet science. Thus, Zaleski describes the establishment of science-production associations to improve the integration of Soviet research and development results with production; he also cites the development of other organizational plans designed to improve the effectiveness of the Soviet economy. However, Katsenelinboigen notes that precautions are taken to insure that any alterations in the bureaucracy will not diminish the Party's power.

In searching for explanations of the poor Soviet technological performance, Amann implies that core causes are elusive:

> The fundamental reason for this is that we do not yet know why Soviet technology is on the whole backward. How the Soviet research and development system operates is the major determinant of the technological performance, and changes in this major condition, less obvious and much more difficult to assess than selected statistics, could have a decisive impact.

However, we suspect that whatever strengthens our perception of the role of Soviet bureaucracy should help to unravel the cause-and-effect relationships.

Fourth, we must recognize the highly subjective approach to the Soviet system characterized by an optimistic or pessimistic perception of our relations. Inevitably, in any analysis of U.S.-U.S.S.R. interactions, the hypotheses, the presentation of data, and the conclusions will depend upon how the Western researcher looks at the knowledge at his command. The optimist tends to give more weight to favorable possibilities over the long term, while the pessimist may be affected by the current evidence of Soviet shortcomings. The optimist may see the possibility of deeper and extensive interdependent ties between the U.S. and the U.S.S.R., whereas the pessimist may see this as impossible, given his projection of current Soviet behavior. The optimist is conscious of the step-by-step process by which human interaction evolves, while the pessimist wants the world tuned to his view instantaneously or gives up prematurely. The optimist knows that American industry is apprehensive about visits of Soviets to its laboratories; the pessimist is incensed when the Soviets fail to bare all their work upon the first meeting. Perhaps these contrasting attributes are oversimplified or not completely accurate, but the factor of optimism or or pessimism in viewing U.S.-Soviet relationships clearly affects the analysts' conclusions and must be taken into account.

Fifth, we tend to judge the quality of Soviet science in terms of the number of Nobel prizes received, a limited and misleading measure. Gustafson points out that many areas of basic Soviet science are in fact held in high regard by foreign peer observers. In this connection, Graham states that:

> Indeed, it is probably no exaggeration to say that the Academy of Sciences of the U.S.S.R. is the most important single scientific institution in the world, since in those countries which equal or surpass the Soviet Union in quality or science or overall scientific effort, fundamental research is dispersed throughout a variety of autonomous universities and institutions, both public and private.

Fusfeld, Amann, Hanson and Holloway conclude that the principal deficiency of the Soviet science and technology organization lies in its inability to effectively apply the results of basic research. Hence, a view which blames the quality of the U.S.S.R.'s science for the backwardness of its technology is wide off the mark.

Sixth, we tend to perceive the U.S.S.R. as a homogenous monolith, without considering individual differences and structural conflicts within the system. To put it simply, the Soviet leadership appears to many Western Sovietologists to be as fragmented on issues as that in the West, despite the Soviet ideological objective of promoting governmental and societal homogeneity. Parrott calls this to our attention by focusing on the differing views expressed by Brezhnev, Kosygin and Suslov on the state of economic development at home and abroad. This diversity also applies to lower levels. Thus, the Soviet scientific community is not monolithic. Indeed, according to Graham, the jurisdictional struggle for power here is clearly evident:

> Some American scientists have spoken about serious competition to the Academy from other Soviet organizations, especially from the State Committee for Science and Technology. Other Western observers have considered it inevitable that Soviet universities would gain in scientific influence at the expense of the Academy, with the result that the organization of Soviet science would become progressively similar to the organization of science in the United States.

Labedz further characterizes the differences within the U.S.S.R. by noting the issues in the administration of science:

> While the post-Stalin science policy removed some of the obstacles to the pursuit of learning in various disciplines, the dilemmas of pure science versus applied science, of centralization versus decentralization, of governmental pressure to subordinate science to the requirements of the economic plans versus the needs of fundamental scientific research have been as vexing as ever....

Seventh, the structure, the product mix and the growth rates of Soviet industry are different from those in the U.S. On this point, Amann comments:

> ... some Soviet industries which have continued to expand rapidly are industries in which the rate of growth has slowed down considerably in other major countries; hence, for example, plastic and man-made fibers have replaced steel and cotton in the U.S.S.R. much more slowly than elsewhere....

Thus, rampant enthusiasm for a new product in the U.S. may leave the Soviets unexcited; conversely, the Soviets may be enthusiastic for a process which the U.S. considers of little importance. Recognizing these mismatches should both provide trade-off opportunities and serve as caveats in dealing with the U.S.S.R.

C. Soviet Perception of Their Own Science

Seven elements in the Soviet perception of their own science can be identified. As the first and undoubtedly most important, science and its role in the Soviet system are viewed in the U.S.S.R. as having more than functional tasks of providing knowledge and adding to material well-being. Science has political, almost religious, functions in at least two aspects:

> It is regarded as an integral part of Communism. Party theoreticians consider that Communism will be progressively refined and strengthened by the results and stimuli of science; and, in a related point,
>
> Science is used by the Party leadership to legitimize its power. Thus, good science is taken to imply effective Party administration. (Both Joravsky and Rabkin discuss science as a legitimizer of the leadership.)

These points are sharpened if we focus on technology and productivity of the Soviet economy. (The latter is viewed as a direct indication of the success of Communism.) Because of a poor productivity record to date and because productivity is limited directly by the effectiveness of technology, the Soviets do not tout their technology. Instead, they link technology to science, which has a better record, and wrap up the whole complex in what they call the scientific-technological revolution. The latter is expected to shape the future Soviet working environment and solve social problems. On this point, Turkevich quotes Party Secretary Suslov on the occasion of the Soviet leader's receipt of the Soviet Science Academy's Marx Gold Medal in 1976:

> Contemporary scientific-technological revolution opens before society unseen possibilities for using science for mastering the forces of nature, protecting it and solving social problems ... and at the same time acts as a material preparation for communist civilization.

This formulation clearly couples science as a magic genie with science as a driving engine of Communism. Labedz notes that this adumbration is not really new since the Czars also enshrined science in their days.

Second, science in the U.S.S.R. is intended to contribute to meeting social and economic needs. The Soviet leadership has expressed this intent on various occasions. Labedz points to one such occasion:

> Khrushchev's "destalinization" after 1956 removed some of these obstacles. Growing attention was devoted to the problem of technological innovation, and science was elevated to the status of a "productive force" in the new Party Program at the 22nd Party Congress, with the implication that it would play a more fundamental role as part of "the material basis" and not merely as an aspect of the "superstructure."

The creation in 1961 of the forerunner of the present State Committee for Science and Technology (SCST), and SCST's growing power since then, are other important indications of the pressure by Soviet leaders on Soviet science to meet the U.S.S.R.'s needs. In fact, the State Committee was set up precisely because of the leadership's dissatisfaction with the Science Academy in meeting Soviet production needs.

Third, the Soviet leaders expect the U.S.S.R.'s scientific community and its programs to be subservient to political needs. Should the Soviet scientific establishment fail to respond to political pressure, Labedz predicts the inevitable outcome: "... the Soviet scientific establishment will, when the chips are down, accommodate itself to the system, rather than the Soviet system accommodating itself to the scientific establishment."

Fourth, science has traditionally been viewed as a vital and respected part of Russian culture, with associated prestige and influence. In contrast to some present anti-scientific trends in the U.S., Soviet science enjoys strong support at all levels of society. Moreover, Soviet science is a distinct and important part of the governmental structure and is incorporated in the official planning process. And, the fact that many of the vocal dissident scientists have to date been protected in most cases against drastic physical repression because they are members of the Soviet science community, owes much to the enshrinement of science. Finally, the creation of numerous science centers, most notably Akademgorodok outside Novosibirsk, together with a plethora of scientific laboratories, also serves as evidence of broad support of science in the U.S.S.R. Graham confirms a continuing and favorable societal view of science: "The commitment of the Soviet government and of Soviet society to the support of fundamental research seems to be firm, and the Academy is the primary beneficiary of that largesse." In this connection, Turkevich notes that the U.S.S.R.'s political commitment to science and technology is symbolized by the fact that most of the 20 members of the ruling Politburo are technologists, as are most of the 60-some members of the Council of Ministers.

Fifth, science is considered to be a key component in Soviet attainment of military preeminence. Holloway argues that because the U.S.S.R. feels it needs sophisticated weaponry, it must increasingly rely upon science to contribute strategic ideas and options. Furthermore, contrary to the generally uneven and inefficient integration of science and technology into production in the civilian sector, the military area is structured to maximize benefits from scientific results. Holloway cautions us, however, that quantitatively sizeable Soviet military capabilities cannot be taken as automatic evidence of superior technology.

Sixth, the linkage between science and technology is not sufficiently developed, accounting in great part for the poor performance of Soviet technology relative to Soviet science. This widely acknowledged weakness of the Soviet system is what Hanson specifically, and Amann and Fusfeld indirectly, refer to as lack of effective vertical integration, i.e., while Soviet scientific knowledge unquestionably can be outstanding, it is not properly utilized within the U.S.S.R. This weakness, which is discussed later in more detail, exists in part by conscious choice: political control takes precedence over efficiency. But the Soviet regime clearly recognizes this shortcoming and has sought many times to alleviate it by reorganizing the Soviet scientific and technical efforts, while at the same time not losing any control. Amann identifies four Soviet programs undertaken to improve the situation. And Zaleski analyzes several recent decrees issued by the Party which, in effect, aim to solve these problems.

Seventh, there is growing Soviet interest in developing a more organized and quantitative view of science. This aims to give the Soviets a more accurate view of their science and presumably a means to improve it as well. To understand the nature of this development, Gustafson analyzes the Soviet view of U.S. science. He argues that how the Soviets interpret U.S. science reveals a great deal about science in the U.S.S.R. itself. In this context, Rabkin describes how the Soviets are developing the discipline of science policy (naukovedenie) and comments on its implications. He is especially impressed by the candor with which the Soviets criticize their own science; he attributes this to a widely accepted Soviet assumption that because the scientific establishment gets preferential treatment from Soviet authorities, it also deserves close scrutiny and criticism when warranted. Rabkin notes that Soviet analysts themselves see restricted communication with scholars abroad as a significant barrier to quick diffusion of information. He speculates on the future of naukovedenie as to whether it will be over-bureaucratized and lose its initial zeal or whether it will eventually provide access to useful and timely information to experts within and outside the U.S.S.R. If the latter proves to be the case, then the correction of some Soviet shortcomings may follow.

According to Gustafson, the Soviets have diligently compared the relative value of the U.S. project-grant system with the longer-term Soviet funding of large institutes. They seem fully aware that the former is more responsive to national needs while the latter may lead to parochialism or irrelevance. Gustafson quotes one Soviet researcher who remarks cynically that

> ... the excessive generosity with which we are funded sometimes creates conditions which support idle exercises for years, under the umbrella of "unlimited freedom of inquiry." The champions of this freedom passionately exclaim, "Who can deny the possibility that my thesis, which seem unpromising today, may not cause a revolution in scientific theory tomorrow!" Then examples are cited from the school child's history of great scientific discoveries....

Gustafson infers that the Soviets seem to have become weary of their own incentive system and may be examining the more productive incentive system in the U.S. for some form of adoption in the U.S.S.R.

D. Soviet Perception of the West

Two ideas seem to dominate the Soviet perception of the U.S. First, despite assertions of their own ideological supremacy, the Soviets consider U.S. achievements as the principal criteria in measuring their own success. In fact, the Soviet goal of "overtaking and surpassing the U.S." dates back to the 1930s. In this context, Parrott suggests that the Soviets find themselves challenged by U.S. progress even more today:

> ... a 1970 article in Kommunist cautioned that "it is extremely dangerous to manifest slowness in using the enormous advantages of socialism over capitalism in the area of the comprehensive and accelerated development of science and technology and the improvement of administration." The implication was that the developed capitalist states had raised a new economic and technological challenge which required that the Soviet leadership respond with major changes of policy.

This challenge arises in the midst of a continuing Soviet habit of borrowing from the West, underscored by Hanson:

> At all events, the situation which Soviet policymakers are trying to alter by international transfer is one in which they currently lag behind the West. There is nothing new about it. Russia has been trying to catch up by importing Western technology, as several writers have pointed out, at least since Peter the Great.

Hanson considers the general Soviet predicament as one of the U.S.S.R. being thrust on a treadmill while simultaneously shooting at a moving target:

> Once it was widely grasped by Soviet managers and planners that catching up with Western technology meant chasing a rapidly moving target over an ever-increasing product range, a shift in policy was almost inevitable.

Holloway identifies the technology gap problem specifically in the military area:

> Military rivalry with technologically more advanced states (which has been such a marked feature of Russian and Soviet

history) has had an important influence on the Soviet military R&D effort. The Soviet Union has drawn considerably on foreign science and technology, not only in the form of imported weapons (mainly in the 1930s and 1940s), but also in the form of design concepts, and more generally in basic and applied scientific research. A second consequence of the rivalry has been that the political leadership and the Armed Forces have made major efforts to extract resources from the economy and the society to meet what they saw as the needs of this competition.

A second element in the Soviet attitude toward the West is their strong desire to be perceived and accepted by the West as a technological equal. To attain this goal, the Soviets take advantage of any opportunity to create a favorable global image of their scientific and technical capability. Certainly, the recent collaborative Apollo-Soyuz space effort fits into this scheme. Beyond this, any U.S.-U.S.S.R. agreement for cooperation in various areas of science serves to promote the Soviet objective. It is not clear whether the Soviet desire for acceptance as a technological equal by the West is motivated by commercial strategy to obtain, by association with the West, greater acceptance of Soviet products or whether it is mainly a matter of prestige.

III. The Structure and Weaknesses of Soviet Science

A. Elements in the Structure of Soviet Science

The principal institutional features of Soviet science can be summarized as follows:

- Soviet science is organizationally linked directly and at high levels to the government.
- The producing elements of Soviet science are laboratories at the Academy, ministries, and universities.
- The State Committee for Science and Technology (SCST) coordinates science within the Soviet Union and with foreign countries, with the State Planning Committee (Gosplan) having some domestic planning functions.

The overall structure of Soviet science is described by Turkevich. Graham discusses the structure of the Academy. Thomas describes the jurisdictional and conflicting mission problems within Soviet science. Adams shows how Soviet science responds to a crisis, as illustrated by developments in biology. Lubrano assesses the professional competence of scientists while Joravsky interprets their intellectual integrity. The problems of integrating science with production — vertical integration — are considered by Fusfeld in overall terms, by Humphrey in terms of an illustrative single industry, by Holloway in a military-related area, and by Amann, Hanson, Parrott, and Labedz in terms of systemic problems.

The workshop papers deal extensively with the Academy and its role in vertical integration; much less is said about the structure and operation of the laboratories in the Ministries. The latter area is less well-known, and deserves more detailed attention. Finally, research at Soviet universities is not discussed at length. In part this reflects the fact that Soviet universities do not play the same extensive role in fundamental research as American universities.

The four critical issues significant to understanding the contemporary structure of Soviet science are:

- The extent of SCST's responsibility for the direction of the Soviet scientific effort.
- The strength of the Academy of Sciences.
- Improvements in the efficiency of vertical integration.
- The possibility of the present vertical integration in the military sector serving as a model for similar structuring in the domestic sector.

Each of these issues is considered below.

1. The State Committee for Science and Technology

In order to define the role of the State Committee for Science and Technology within the structure of Soviet science, Graham analyzes the Committee's impact on the Academy. In responding to a view of Western scientists on the possible decline in the influence of the Academy, Graham states that the SCST indeed encroaches the most on the traditional hegemony of the Academy. This starts with political protocol: the head of the SCST, who is also Deputy Premier, outranks the President of the Academy in the Council of Ministers of which both are members. Beyond protocol, the SCST facilitates and coordinates all aspects of science in the U.S.S.R. as well as science relations with foreign countries. Graham points out that SCST also selects priority projects for U.S.S.R.'s National Plan:

> The State Committee periodically compiles a list of the current 200 to 250 most important scientific-technical problems facing the country and works with the State Planning Committee (Gosplan) in seeking their solution.

But the SCST may exert its most decisive influence on the direction of Soviet science by its financial leverage. According to Graham, the SCST annually receives 2-3% of the total R&D budget to be distributed as SCST seet fit. This is persuasive leverage for appealing to the self-interest of Soviet scientists. On the other hand, an optimist might view this capability of the SCST as a way of getting the Soviet laboratories to conduct science which is both high quality and relevant to immediate needs.

While the SCST does not have scientific in-house capability, it integrates the input from the scientific community through a system of advisory subcommittees and scientific councils; as Graham points out, this gives the SCST the voluntary assistance of thousands of Soviet scientists, including most Academicians. Of course, the SCST retains the executive authority over these bodies.

If the aphorism that success breeds success applies, the influence of the SCST will grow. One can speculate that its financial leverage, institutional flexibility, and network of contacts may prove effective tools for improving performance along the entire Soviet science-technology spectrum while at the same time reducing into impotence those organizations which do not comply. However, it should be noted that the SCST is itself a large bureaucracy and may not effect its intentions of providing productive leadership.

2. The Academy's Strength

The Academy is a pervasive and enduring institution in the Soviet system. Pressures on it for relevance have been exerted spasmodically throughout its life, according to Labedz:

> Soviet science policy reflected from the beginning some ancient problems in this field. When Peter the Great founded the St. Petersburg Academy of Sciences in 1724, it was given the task not only of carrying out scientific research but also of helping the government to solve practical problems. Its statute made it mandatory for its members to work on projects given to them by various departments of the government. With time these obligations fell into disuse as the academicians tended to pursue knowledge for its own sake. But the first World War and the October revolution in particular reversed this trend.

After the Academy lost in the early 1960s jurisdiction over laboratories engaged in applied science — approximately 40% of the total Academy laboratories at the time, according to Graham — it retained the primary mandate for conducting fundamental science in the Soviet Union. According to Graham, the incentive for this change came from within the Academy:

> The removal of the industrial research institutes from the Academy in the early sixties was not an action that was forced on the Academy, but a reform that was strongly supported by an influential group of Academy members working in the basic sciences, particularly chemistry, physics and mathematics. These scientists wanted to correct what they saw as an exaggerated emphasis on applied research during the Stalinist period.

A cultural subtlety identified by Graham tends to confirm the continued vitality of the Academy:

> Whether one is interested primarily in promoting intellectual quality or defending those areas of relative political autonomy which exist in the Soviet Union, the Academy is a precious institution to the Soviet intelligentsia. This alliance of establishment and non-establishment sentiment is rare among intellectuals in the Soviet Union, and is one of the

hidden strengths of the Academy.

The Academy also exerts a decisive influence on the quality and permanence of fundamental science through its influence upon university education. Graham states:

> Many of the academicians and leading researchers in the Academy also have connections with the universities. When they identify bright and promising young students at the university, they often invite them to participate in research in the institutes of the Academy, which, like the universities, have the power to award advanced degrees. The negative side of this process is that the universities have difficulty building up an independent research system of high quality, since the Academy often takes their best students.

The Academy's mandate for fundamental science has been skewed somewhat by continuing government pressure for relevance. However, the extent to which this pressure affects laboratory programs is questioned in the analyses of Gustafson, Adams, and Rabkin. Adams demonstrates how the Academy adroitly dealt with Lysenkoism by simply incorporating the needed biological science into institutes with responsibilities in other subject areas. Gustafson as well as Rabkin show that research mandated through budgets are not perceived or acted on by the bench scientists; moreover, they can work, bureaucratically insulated and deep in the institutional labyrinth, on essentially whatever pleases them.

Graham concludes his analysis by saying that, on balance, the Academy has to date retained its institutional strength, though ultimately this will depend on the activity of the State Committee with which the Academy must willy-nilly interact.

3. Problems of Vertical Integration

While contributors to this volume comment extensively on the weaknesses of vertical integration in the U.S.S.R., few describe the interacting institutional elements except for Humphrey, who deals with the Soviet development of enriched feed from single cell protein. Instead, the discussion of vertical integration has focused more on political and cultural, i.e., systemic, causes. In this overview, the vertical integration problems are dealt with in the "weaknesses" part of this section and in the final section concerning obstacles to interaction.

4. The Interaction of the Military Sector with Civilian Science

Soviet military programs interact with non-military science in several important ways. Holloway unravels a thread which winds from Trotsky to Brezhnev and examines the commonly accepted notion that the level of military technology in the U.S.S.R. is higher than that of civilian technology; this gives rise to the view that the Soviet civilian sectors should adopt the military approach. Holloway ascribes the sophistication of military science and technology to two factors: first, the increasing complexity of military weaponry requires a more refined scientific input; second, the scientific community in turn proposes weapons, the potential of which stuns even the military. Holloway summarizes the interaction of science and the military as follows:

> First, "while in relation to production, science is becoming a direct productive force, in terms of military affairs it is gradually becoming their most important element;" modern weapons cannot be created without the application of scientific results from a whole range of disciplines. Secondly, scientific progress has outstripped military affairs and is throwing out new possibilities for weapons development. Thirdly, before the Second World War it was, as a rule, the applied and technical sciences that influenced the development of weapons; but now basic research is coming to have a direct and immediate impact. Fourth, all scientific research is relevant to defense: "Now it is impossible to name with firm conviction any branch of natural science which would be neutral or unnecessary for the development of military affairs. Any branch of natural science either already takes part, or can potentially be used in (military affairs)." Fifth, the creation, production, operation and control of modern military equipment is so complex that not only are scientists drawn in to work on military problems, but many officers have to become scientists in their own right.

Holloway suggests that the present nature of the interaction between the Soviet military and science derives from the competitive struggle with the West; from the substantial military pressure to meet schedules and quality criteria; and from the high priority and quality which the military demand and get in both materiel and personnel. Regarding the attraction of top scientists, he notes an interesting impediment which no doubt decreases the appeal of work in military laboratories:

> The defense sector has first priority in the allocation of materials or parts which are in short supply. Engineering-technical personnel in the defense sector are better paid than those in civilian industry, and, by and large, the workers also receive higher wages than in civilian production. It does not follow, however, that the quality of personnel is in fact higher, for many scientists and engineers, in particular those who seek recognition through publication of their work, find the secrecy stultifying and are thus not attracted by the higher pay.

Holloway cites another element linking the military with science and the economy, viz., the fact that 42% of the production of the military plants is directed to the civilian economy, mostly the transportation industry. This is not to discount the weight of the military. Thus, in discussing the impact of the current Tenth Five-Year Plan on the Soviet economy, Bush presents statistics that show the military sector taking 11% of the 1975 GNP of the Soviet Union;

moreover, he asserts that the military's share of production of consumer goods will rise from 18% in 1975 to an expected 22% in 1980.

Historically, Holloway points out that many of the important and more sophisticated military projects were initiated under the aegis of the Academy and only later were separated from the Academy:

> The Academy may well have had a role in military R&D for the "traditional" defense industries, but its most important military work was in the development of advanced technologies. In the summer of 1943 a special laboratory had been created in the Academy to work on the development of the atomic bomb. This later became the (Kurchatov) Institute of Atomic Energy and remained part of the Academy until 1961.

B. Weaknesses in Soviet Science

Soviet science may be considered "weak" if judged by Western standards; but using our criteria may possibly prevent more accurate understanding of the adequacy of Soviet science within the Soviet system. A criterion that may be adequate for gauging the Soviet system is the relative self-sufficiency of the U.S.S.R. in meeting its desires. Such a criterion may be irrelevant to a country without natural resources, without a cultural environment receptive to the pursuit and use of science, or without effective communication with the industrialized world. The U.S.S.R. is clearly free of such limitations. Therefore, any major requirement for imports by the U.S.S.R. is a sign of inadequate organization and utilization of the country's resources — material, intellectual, and labor — to meet national objectives.

The persistent efforts of the U.S.S.R. to import Western technology partly reflects "weaknesses" in terms of this criterion. However, the principal reason for the Soviet need may be Soviet assent to allowing the West to set standards for achievement. In effect, the Soviets may have permitted themselves to become slaves to goals set by the West and not by the U.S.S.R. itself. An inevitable pressure then develops to turn to the West for advanced technology. Undoubtedly, the Soviets view this as a temporary condition, and that their desires and their own ability to meet their needs for such technology will soon converge. But the authors in this volume express doubt about such convergence, given the fundamental sluggishness of the Soviet system.

Both Western and Soviet critics identify two paradoxes concerning the effectiveness of Soviet science:

> If Soviet science and technology is so good, why import from the West?
>
> If the Soviet regime wants to improve vertical integration, why not eliminate the stifling bureaucracy, rigid planning, and overemphasis on quantitative, rather than qualitative, production goals?

Labedz comments directly on the first paradox:

> There are indeed many ironies in the situation. The Soviet system is allegedly based on a scientific theory

("scientific socialism"). Moreover, the prestige of science in the country has always been high, and yet after it has been enhanced even more by being officially declared "the force of production" in the new Marxist framework, the Soviet Union is forced to implement the belatedly-discovered "scientific-technological revolution" by imports of Western technology.

Parrott notes further the unsettling ideological implications raised by import of Western science:

> Today, as in the past, the Soviet Union's economic and technological performance in comparison with that of Western countries has profound implications for Soviet military and political influence abroad. It also has serious implications for the Soviet elite's professed belief in their own political system as the most modern and dynamic.

Labedz suggests that the repeated Soviet reliance on the West may create a continuing dependence — and consequent weakness — such that the U.S.S.R. becomes addicted to periodic infusions of Western technology. Presumably, this view of dependence should not be pursued to such an extreme as to lead us to grossly underestimate the underlying strength of the Soviet system. Nevertheless, reliance on Western science began with the Czars and has continued since despite the changes in governmental systems, viz., from Tsarist to Soviet. Even recent changes within the U.S.S.R. have not reduced Soviet dependence on the West. Thus, Thomas notes that Soviet leaders cannot terrorize their scientists today as Stalin could and did in his days. Yet the low Soviet productivity on the whole and the resultant need for external aid remain. In this context, Holloway quotes Sutton, who has done the definitive study of Western technology transfer to the U.S.S.R., on the paradox of Soviet innovation — an extraordinary lack of effective indigenous innovation in the civilian sector versus relatively effective procedures in the military sector.

The foregoing comments are intended to indicate that the general weakness of Soviet science stems from a complex mixture of Soviet systemic deficiencies, Russian historical development, and cultural background.

More specifically, twelve weaknesses affecting Soviet science and technology can be identified in the system.

First and foremost, is Party interference in science affairs, as described by Graham, Katsenelinboigen, and Thomas. The point is epitomized by Graham:

> At the 24th Party Congress in 1971 the Party Statutes were revised to give Party organizations in fundamental research institutions greater control over research administration. The effects of this change in the statutes were felt primarily in the Academy of Sciences. Paragraph 60 of the Party Statutes had earlier exempted non-industrial (academic) research institutes from administrative control by the primary Party organizations.

And Katsenelinboigen notes that the Party continues to interfere directly with the economy:

> The Party apparatus is another user of the economists' work. The Party apparatus, as is well known, fulfills a dual role in the Soviet society. On the one hand, it formulates and implements ideological policies. On the other, it intrudes directly into the economic life of the country and participates actively in the process of shaping and fulfilling economic plans.

In this connection, Thomas notes that the Party's intrusion into Soviet science and technology has traditionally been triggered by its efforts to maintain control in all spheres of the Soviet system (the military, arts and literature, etc.), even if this has to be done — as in the past — at the expense of efficiency.

Second, inflexible planning and management — a reflection of overcentralized authority — discourages productivity. Reorganizations in the late sixties designed to stimulate production only increased the authority of the central organizations. As Zaleski notes: "There is some evidence that research institutes currently are subject to tighter controls by the agencies to which they are accountable." In a comparable vein, Holloway considers the military rigidity to be stifling:

> The third concern is that, in spite of its relatively successful operation, the military "research-production cycle" is not flexible enough to cope with present requirements. One military writer has commented that "the search for a more flexible organizational structure for research establishments is one of the ways of raising the effectiveness of scientific research in the interests of the country's defense."

In broader terms, Parrott also notes the effect of rigid planning on Soviet economic performance:

> Taut planning also makes the participants less willing to accept the economic risks of innovation. All this is a familiar syndrome, but its consequences for technological innovation are graver than for other types of activity.

Third, the stifling effects of historical Russian bureaucracy have already been identified in this discussion. Even the Soviets recognize the pervasiveness of their own bureaucracy which seems to be rooted in a cultural propensity for avoiding risk and responsibility. As a result, the cumbersome administrative machinery substantially diminishes the vitality of the economy.

Fourth, the preemption of resources by the military, who have first call on scientists and equipment, affects negatively the efficiency of the civilian sector.

Fifth, dependence on the West for scientific input is a self-perpetuating weakness which may grow with time.

Sixth, resistance to technological change and specifically to innovation in the industrial sector is widespread in the U.S.S.R. This exists because potential changes are viewed as threatening fulfillment of near run production quotas on which career advancement depends. As Katsenelinboigen notes:

> ... A threat that this may curtail the authority of the Soviet management apparatus, the inability to implement new methods of planning, etc., have led many Soviet managers to oppose the introduction of new economic methods.

In a related vein, Thomas notes that innovation is resisted because no allowance is made by the political leadership to the production ministries for the fact that production goals might be missed because of downtime required to re-equip plants with new machinery and to re-train workers to use that equipment.

Seventh, lack of technical management and organizational infrastructure restricts the flow of new industrial products and processes. Labedz points out that:

> It is obvious that for new technology to function effectively it is not sufficient to copy the hardware; it is also necessary to create organizational and managerial infrastructure, as well as the pattern of rationality which would permit it. This raises the perennial problems of ideology versus rationality and of apparatchiki versus technocrats in the absorption of — say — computer technology into the Soviet system.

Eighth, political dominance over science affects the quality of scientific personnel. While Soviet science is considered by Western peers to be excellent in many respects, Joravsky implies that its representatives do not always sustain its excellence, whether by choice or by force. Adams addresses the ambivalence of Soviet scientists, operating in a highly politicized environment:

> ... Nor should we be surprised to find many Soviet scientists who had risked political difficulties to defend genetics now signing petitions against Sakharov: scientists speaking on political matters threaten to undo the symbiotic relationship predicated on the separation of science and politics, and invite the kind of political interference in science which led to the Lysenko problem in the first place.

Ninth, the inability to successfully integrate science with production and marketing is a recurring theme in discussion of Soviet weaknesses by Hanson, Fusfeld, Amann, Parrott, and others. Analyzing the problem, Parrott points to the lack of incentives to promote competition. He concludes that the problems are rooted more in the rigid structure than in personnel.

Tenth, slow diffusion of information within the U.S.S.R. impedes scientific achievements. Hanson blames the sluggishness on low credibility of regime-supplied information. Other reasons for slow diffusion include lack of photocopy machines, a scarcity of advertising literature, and ineffective technical professional societies.

Eleventh, there exist difficulties in relating science to broader economic goals, as discussed by Zaleski and Labedz. The former comments that:

> One of the greatest difficulties in planning science in the U.S.S.R. is to connect it to broader economic goals. The difficulties encountered in this area have been noted continuously. Recently, the Soviet government made a special effort to solve this problem by devoting — for the first time — a special chapter in the national plans on the planning of science and technology. The effort attempts to link R&D with production by prescribing in detail the transfer of new technology and research results to the production process....

In this connection, Zaleski discusses numerous efforts to reorganize the Soviet research and development structure to strengthen the effect of science on economic growth.

Twelfth, insufficient material incentives for innovation undermine the effectiveness of scientific activities. Honorary titles and medals apparently do not provide sufficient incentives for the average Soviet citizen to increase his productivity.

IV. Opportunities and Obstacles in U.S.-U.S.S.R. Cooperation

In addition to improving our understanding of Soviet science, the analyses in this volume are intended to provide guidelines for consideration by those in government, industry, and universities whose responsibilities involve direct interaction with the U.S.S.R. This section discusses specific operational ideas. In considering how these ideas might best be organized, we decided to use the barter paradigm because the U.S.-U.S.S.R. interactions seem to be dominated by perceptions of equivalent value that go beyond strictly monetary transactions.

In any barter interaction, the bargaining parties, intuitively or explicitly, make two preliminary assessments: 1) what are the perceived needs of the two parties? 2) what are the impediments and, in reverse, the facilitating factors? The barter then proceeds until a perceived equality of satisfaction is achieved; the magnitude of the exchange depends on the degree of success in overcoming impediments.

Thus, the following discussion considers from a U.S. viewpoint these operative questions: what does the U.S. require? What does the U.S.S.R. require? What factors in the U.S.S.R. will facilitate transactions? What factors in the U.S.S.R. will impede transactions?

A. U.S. Requirements

Since the workshop focused on Soviet needs with reference to the Soviet system, our comments on U.S. requirements are brief. There is little question that the U.S. needs relative to the U.S.S.R. involve at least the following:

1. In foreign policy, our principal need is the easing of tensions with the U.S.S.R. This was stressed by Ganley in his remarks to the workshop.

2. In regard to commercial interests, there is continuing pressure for increasing commercial relations with the U.S.S.R. It is perceived that expanding markets aid economic growth within the U.S. and reduce our trade imbalances. Moreover, it is generally presumed that increasing interdependence through commercial relations contributes to easing tensions.
3. In science and technology, cooperative relations may contribute to increasing U.S. strength. The scope and intensity of Soviet scientific commitments increase the possibility that the U.S.S.R. will become a major source for new scientific advances. While lagging behind the U.S. in most areas today, the U.S.S.R. has demonstrable potential in many areas. Therefore, even though benefits to U.S. science and technology from cooperation with the U.S.S.R. may be minimal today, they could increase under the right circumstances.

B. U.S.S.R. Requirements

Soviet requirements are cultural-political as well as economic, and these are often interdependent. U.S. initiatives which meet these requirements should obtain corresponding U.S.S.R. concessions relevant to U.S. needs.

In considering the question of Soviet needs, the U.S. should recognize that by setting global trends it contributes to increasing the Soviet requirements. Thus, as the U.S. continues its steady advance in technology, the gap between the U.S. and U.S.S.R. widens further and therefore defines even greater U.S.S.R. needs. Naturally, it is not in the interest of the U.S. to minimize its quest for technological breakthroughs and innovative approaches. However, as the U.S. continues to function as the yardstick for the U.S.S.R., it is, by developing more sophisticated products and processes, creating a gap that may not be closed in the near future, if ever. Indeed, Hanson, Parrott, and Amann observe that, if anything, the gap is progressively widening. Unwittingly, the West makes the Soviets more dependent on external sources, not only by defining the upper parameters of needs but also by provoking the Soviets to come to the West for instant transfusions rather than to depend on their own slower paced developments. Since, as Fusfeld clearly shows, the Soviets do not integrate their R&D, production, and marketing effectively, in many cases they are already behind when the race to develop a new product begins — computers are a case in point.

Their need for technology from the West is quantitatively estimated by Green and Levine; they assert that the Soviet investment in Western technology returns three to four times as much as the same investment in domestic technology. While Hanson questions the magnitude of the return, he acknowledges that the idea is basically correct. Green and Levine further note that 8% of the Soviet growth in the 1968-1973 period could be attributed to Western machinery.

Some of the U.S.S.R. requirements described below are restatements of the characteristics of the Soviet system presented in earlier parts of this overview. They are collected and enumerated here for U.S. consideration in interactions with the U.S.S.R.

First, the Soviet need arising from the discrepancies between anticipated and the actual effectiveness of the Communist system is exemplified by the deficiencies of Soviet industrial enterprises. Their relatively poor performance is inconsistent with either ideological or economic goals. As a result, the U.S.S.R. promotes major interaction with the West to make up for its deficiencies.

By contrast, basic science in the U.S.S.R. cannot on the whole be considered deficient. Graham notes that the U.S.S.R. Academy of Sciences is the most respected single institution in the U.S.S.R. Competent academicians are found in all laboratories: university ministry, and Academy. Turkevich notes further that the dispersion of academicians within Soviet institutions gives the Academy power and influence which are unique in any society. If there is a deficiency in Soviet science, it is, according to Gustafson, in its organization and the utilization of its research output.

Preoccupation with production goals prevents Soviet enterprises from establishing more productive relationships with the science community, i.e., the development of new products and processes is frustrated by commitments to existing production methods which turn out inferior products. As a result, the Soviets turn to the West for whole new plants and processes which can be plugged into their economy as a substitute for indigenous development. But their society is then cheated of incorporating preliminary trial-and-error experience into its technological culture; this contributes to the U.S.S.R.'s systemic weakness.

Second, the Soviets aim to strengthen their science as a base for developing their military power. Soviet military requirements play a major role, given the Soviet leaders' superpower ambitions. Since Khrushchev's days, these have been described in terms of the U.S.S.R. being a <u>velikaya derzhava</u> (great power) with incontestable rights to assert its interests in all parts of the world. In this context, we can fit Holloway's conclusion that the foundation for the priority scientific effort in the U.S.S.R. is the meeting of military requirements by whatever means and from whatever source, Soviet or Western. And as military weapons become increasingly complex, this leads to greater reliance on basic science; in turn, this results in Soviet science devoting more effort to meeting military rather than civilian needs. But because it cannot provide all the answers to the production of sophisticated military hardware, this increases the pressure within the U.S.S.R. to obtain new techniques and ideas from external sources. Consequently, one cannot avoid facing the implication that Western science is likely to be incorporated into the Soviet military and that part of the Soviet initiative to establish science exchanges with the U.S. arises from military needs. In this connection the military origin of the State Committee for Science and Technology (SCST) should not be overlooked. Holloway reasons that:

> Much research of military importance is done in the "civilian" sector, and it seems likely that the State Com-

mittee has a role in fostering and directing research of military interest, and in drawing military attention to promising lines of research.

Third, the Soviet goal of achieving international recognition and prestige equal to the West reflects a national need. Thus, if the Soviets are partners with the U.S. in scientific exchanges, they are viewed by others in the world as equals of the U.S. The Apollo-Soyuz space rendezvous illustrates the point: the joint effort has created a perception among some of equality between the two nations. By consciously nurturing such an image, the Soviets hope to use it to negotiate more effectively with other countries. We conclude that the Soviets will propose some joint projects designed to promote the image of U.S.-Soviet equality in both science and technology.

Fourth, the Soviets seem to require a rational approach that avoids risks. They are more sensitive than Western nations to the embarrassment of failure. Moreover, in their more structured system, fewer options are available once failure occurs. As insurance in the event of such an eventuality, the natural reaction of Soviet officials is to avoid making decisions that can be traced to them individually. Thus, one can assume that, in dealing to obtain science and technology from the West, Soviet negotiators can adroitly pass the buck to their leaders who initiated the interactions with the West or, preferably, to the West. This probably accounts for the extreme guarantees required by the Soviets on various license arrangements and turnkey projects. The preoccupation with avoiding risks is well summarized by Parrott; he notes that Soviet plant managers prefer to maximize their personal job security, even if this involves overregulation and excessive limits on their production freedom, rather than to be given free market choices.

Fifth, the current Soviet need for hard currency affects their negotiating position vis-a-vis the West. Indeed, the situation may force them to give up a number of large turnkey projects in favor of licensing agreements with the U.S. Although, as Bush emphasizes, the Soviets are reluctant to sell their natural resources, their present trade deficit of some $35 billion may force them to reconsider. To further reduce their currency problems, the Soviets want to sell their finished products on the world market. However, according to Bush, the quality of Soviet goods is on the whole shoddy, making the Western countries reluctant to purchase them. In any case, the perennial Soviet hard currency problem gives the U.S. an advantage in transactions with the U.S.S.R.

Sixth, science helps provide legitimacy to the communist system. The mandate for science arising out of communist doctrine has already been identified. To the extent that Soviet science is strong, influential, and a major source of economic strength, the rule of the leaders is legitimized. Science adds to their security because its achievements provide a critical margin for stabilizing their political power structure.

C. Facilitation

The major facilitator of U.S. initiatives toward the U.S.S.R. over the long run is the array of Soviet requirements; it creates great receptivity on the part of the Soviets. The role of specific needs varies cyclically and depends on the political climate at a given time. Below we examine several mechanisms by which U.S.-Soviet transactions can be facilitated.

Organizationally, the U.S. entry into the system of Soviet science and technology is encouraged by the high level connections between science and government in the U.S.S.R. Thus, the starting point for U.S.-U.S.S.R. technical exchanges, and also those related to trade, is the State Committee for Science and Technology (SCST). Its high political status insures the necessary contacts throughout the Soviet system. The fact that the SCST has organizational flexibility and direct institutional responsibility for coordinating all Soviet science and technology means that it can put Western organizations in touch with their Soviet counterparts.

Similarly, the Academy of Sciences has high level political ties and is operated by a strong, central command. All Academy institutes are linked by a central organization; their activities with many university and ministry laboratories are also conducted through a central organization. Therefore, the Academy provides a single mechanism for almost all cooperative ventures in basic science.

The Soviet production ministries, along with their "enterprises," and the U.S. private sector are encouraged to establish direct contacts under Article IV of the U.S.-U.S.S.R. Agreement on Scientific and Technical Cooperation, even though the focus of the Agreement is on science and technology. Thus, some commercial arrangements could be expedited by the mechanism of Article IV, often with the active involvement of the SCST.

Another major factor in facilitating U.S.-U.S.S.R. cooperation is the cultural predisposition of the Soviet people towards science. Anti-intellectualism was not part of the Russian people nor is it of Soviet society. The broad societal acceptance of science is reflected in the steady growth of R&D budgets in the national plan, and in the establishment of science cities such as Akademgorodok, near Novosibirsk. Science support in the U.S.S.R. will probably enjoy uninterrupted support and stability in the future.

Interestingly, the Soviet military may be another facilitating factor. This is due not only to the need for advanced Western science and technology related to military weapons development. Rather, the effectiveness of the military in organizing the vertical integration of science with production may be progressively adopted in the civilian sector. Any resulting improvement in the quality of Soviet science and technology would make cooperation of greater interest to the U.S. because of presumed benefit it could derive.

Finally, there is a clear trend in the U.S.S.R. towards improving the incentive system in order to create greater responsiveness to new ideas. The Soviets appear to have concluded that this path, while politically questionable, may nonetheless be pragmatically necessary. If reforms are adopted, they might make the Soviets more receptive to U.S. inputs.

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D. Obstacles

Numerous obstacles stand in the way of large scale U.S.-U.S.S.R. cooperation. First and foremost is the general concern of the Soviet regime about the contaminating effect of contacts with foreigners on the Soviet people. Some institutions of the Soviet system are deeply troubled by this and actively oppose interaction with the U.S. These are principally elements in the Party and the secret police (KGB). Concern for preserving ideological purity of the Soviet people and fear over compromising national security are the ostensible reasons. But strong elements of traditional Russian xenophobia are also at work. These factors are responsible for the careful selection of Soviet people involved in direct interaction with the U.S. The overriding criteria for such selection seem to be political reliability, with technical competence only a distant second; this situation impairs the quality of U.S. scientific cooperation with the U.S.S.R.

The next greatest single impediment to interaction between the U.S. and U.S.S.R. is the fear of Soviet citizens of the risks involved in contacts with foreigners. This prevents them from making personal commitments or taking responsibility. The situation can be traced to the days of the Czars, but seems worse in the present Soviet system. The overwhelming Soviet governmental bureaucracy is the most visible as well as the most stultifying expression of the Soviet propensity for risk avoidance. Several papers in this volume make it clear that even some Soviet officials resent this burden, despite the fact that it is self-inflicted. In addition to the bureaucracy of the planning organizations and the ministries which may be viewed as monitoring organizations in the system, the Party has a parallel structure which oversees all aspects of Soviet scientific and technical activities. And, as if this is not enough, the KGB exerts direct and indirect influence on the contents of published papers, on foreign trips of Soviet scientists, and on the access of foreigners to the Soviet people and institutions.

These multiple layers of organizations for surveillance provide the pressure for risk aversion. Moreover, national and subordinate plans foster the excessive emphasis upon central planning, which in itself is immobilizing. If the plan is extensively organized, no one takes risks; and if the planning organization is large enough, no one can be blamed. Caution is abetted by the fact that if an error occurs, the system unfailingly identifies an unfortunate scapegoat whose demise somehow absolves the system.

It is surprising that a system which places so much ideological emphasis on scientific approach has been able to make the progress to date it has in the face of a choking bureaucracy. One can speculate that the current great preoccupation with cybernetics in the U.S.S.R. is, in part, a vicarious yearning for the abstractions of feedback processes which might provide the flexibility and vitality absent in real-life.

The reality of an entrenched Soviet bureaucracy impinges upon the West in many ways. For example, in commercial interactions it leads to Soviet pressure for unreasonable contractual terms and for unattainable specifications, to frustrating delays, and to unfulfilled expectations.

A third, serious impediment to wider U.S.-U.S.S.R. interaction is the Soviet lack of hard currency. This limits major cooperative ventures involving Western technology. The problem is exacerbated by the difficulties the Soviets encounter in developing hard currency reserves. One solution to the hard currency problem generates its own impediments. Commercial projects have often been proposed in which the Western investor would be paid "in kind," that is, by gas, oil or metal produced with Western know-how and investment. There is some internal Soviet resistance to such proposed arrangements, however, on the grounds that this is giving away natural resources which are the foundation for U.S.S.R.'s own future economic development and growth. These objections must be recognized in planning major industrial projects in the U.S.S.R.

A final obstacle arises from the Soviet regime's attitude and practice regarding the availability of data. Even most trivial information, or comparable data which is routinely made available in the West, is often withheld by the Soviets; in other cases, the information made available is suspect as to accuracy or completeness.

V. Concluding Thoughts and Perspectives

This volume examines in detail those components of the Soviet system which relate to or affect Soviet science and technology. The discussion of these varied aspects at the workshop produced a perspective on Soviet behavior that can serve to guide our present and future interactions.

Specifically, this perspective includes the following elements:

1. The Soviet, as well as the earlier Tsarist, system has depended on Western science and technology. Barring drastic internal political modifications and economic reform, the U.S.S.R. will continue to need significant inputs from the West if it is not to fall further behind the U.S. in technology across the board.
2. If achieved, massive Soviet imports of Western technology and science know-how could ultimately provide more and better policy options to the ruling Soviet gerontocracy in meeting the problem of allocating limited resources between the U.S.S.R.'s military and civilian needs.
3. However, offsetting any advantage gained by massive imports of Western science and technology may be Soviet inability to effectively and efficiently apply foreign know-how and equipment.
4. Soviet Union's traditional and continuing emphasis on military and heavy industry development heavily dictates its priorities in the selection of areas for U.S.-U.S.S.R. scientific-technological cooperation.
5. Joint activities and contacts of Soviet scientists with foreign scientists are closely directed and continually monitored by the Soviet regime; this serves to constrain personal and professional contacts and produces continuing tensions

between a regime determined to maintain control and Soviet scientists seeking greater freedom for less guided research and open-ended contacts with their counterparts abroad.

To the foregoing, a principal element affecting the U.S.'s own judgemental capabilities should be added: information in the U.S. on Soviet Union's scientific and technological capabilities is dispersed among numerous individuals and institutions; consequently, the U.S. lacks a coherent perspective on the basis of which to develop an effective long-term policy for cooperation with the U.S.S.R. in science and technology; it should develop such a perspective if it is to maximize the benefits from such cooperation and safeguard more completely its interests.

While the papers in this volume identify the reasons for the U.S.S.R.'s desire for Western science and technology, they also imply potential benefits of such exchanges to the U.S. Consequently, we can expect both sides to continue cooperative efforts in science and technology. In this context, any improvement in our understanding of the Soviet system can only enhance our current and future programs with the U.S.S.R. Whether specific interactions are possible or desirable for us depends greatly on our evaluation of Soviet scientific and technical requirements and activities in the broad context of the Soviet system as a whole. To develop such a comprehensive picture and appreciation of Soviet complexity was the principal objective of the workshop and, it is hoped, is the achievement of this volume.

2

SOVIET MILITARY R&D: MANAGING THE "RESEARCH-PRODUCTION CYCLE"

by David Holloway

Introduction

A proper understanding of Soviet science and technology and their relationship to the military requires an examination of the Soviet military research and development effort. This effort absorbs a large part of the resources devoted to R&D in the Soviet Union. It is, unfortunately, difficult to establish precisely how large the proportion is: estimates range from 40 to 80 per cent.[1] Whatever the true figure may be, our picture of Soviet science and technology will be seriously lacking if such a large part of it is left uncharted. What this paper seeks to do is to outline the institutional framework of the military "research-production cycle," and to identify the agencies which plan and manage the cycle and the establishments which carry out the research and development work.

Although there is no agreement on the size of the military effort, there does exist a general consensus that military R&D is more effective than civilian R&D in the Soviet Union. Various explanations have been given for this. The most common is perhaps that the defense sector has enjoyed the highest priority in the allocation of resources. It has also been argued, however, that the relative success of military R&D is the result of the Armed Forces' ability to impose their wishes on the processes of innovation and production.[2] In other words, the effectiveness of the military effort is to be explained not so much by the resources devoted to it, but rather by the efficiency with which those resources are translated into military equipment. These two explanations are not necessarily mutually exclusive, for it is possible both that the military effort enjoys priority and that it is better managed. But if military R&D is better managed, then less weight needs to be given to the resources devoted to it in explaining its relative success. Consequently, this paper looks particularly at the military role in managing the "research-production cycle."

This paper does not claim to provide a comprehensive analysis of the Soviet military R&D effort. Some very important issues are omitted, or merely touched on in passing, such as for example: The size of the military R&D effort; the role of the arms race in stimulating technological progress; the importance of foreign science and technology to the Soviet military effort. Nevertheless the paper does suggest conclusions which are not only important in themselves but are relevant to these issues.

The Level of Military Technology

It is commonly accepted that the level of military technology in the Soviet Union is higher than that of its civilian technology. Forty years ago Trotsky wrote that "the machinery of destruction is of better quality, not only than the objects of consumption, but also than the instruments of production."[3] Soviet leaders have echoed this assessment. In 1962 Khrushchev called for a reorganization of civilian R&D along the lines of military R&D, because the latter had been successful in developing advanced weapons.[4] At the XXIV Party Congress Brezhnev spoke of the "high scientific-technical level" of the defense industry and the need to transmit its "experience, inventions, and discoveries to all spheres of our economy."[5] Foreign students of Soviet technology have agreed with this general verdict. Thus Sutton, at the end of his exhaustive study of Western technology and Soviet development, writes that "Soviet innovation presents a paradox: an extraordinary lack of effective indigenous innovation in industrial sectors is offset - so far as can be determined within the limits of open information - by effective innovation in the weapons sectors."[6] A similar assessment is to be found in most of the Western writing on Soviet R&D.[7]

Nevertheless this assessment should be qualified in two ways. Firstly, it cannot be said that the level of Soviet military technology is as high as the most advanced foreign technology. The technical comparison of weapons systems is methodologically very complex, and it is easy to confuse two distinct categories: military effectiveness and the level of technology. There is no necessary relationship between the two: a higher level of technology will not necessarily lead to a superior capability, while a better capability cannot be taken as conclusive evidence of a higher technological level. Within certain limits, designers can create equipment not inferior to its foreign counterparts, even though the technology embodied in the component parts is of a lower level. In other words, design is the process whereby the whole is made greater than the sum of its parts, and consequently it intervenes in the relationship between technological level and military effectiveness. Thus the undoubtedly formidable power of Soviet armament cannot be taken as evidence that the level of military technology is as high as in the United States.[8]

Secondly, a distinction can be drawn between military and civilian technology insofar as the former is specifically designed for use in war. There is nevertheless a considerable overlap between the two, and the distinction grows more blurred the closer one moves towards the research end of the "research-production cycle." Moreover, much development work on military technology may be indistinguishable from the civilian effort: this could be true of computer technology, for example.[9] It seems to follow that the more advances in military technology come to depend on a large R&D effort, the greater will be the overlap between civilian and military. Of course it is necessary to distinguish between the more advanced and less advanced areas of military technology, but there can be little doubt that the relationship between military and civilian R&D has changed as weapons development has come to depend more and more on basic scientific research.

The growing dependence of weapons development on scientific research is seen as part of the "scientific-technical revolution" and has been the subject of much discussion in the Soviet Union.[10] Several features have been identified in this new relationship. First, "while in relation to production science is becoming a direct productive force, in terms of military affairs it is gradually becoming their most important element;" modern weapons cannot be created without the application of scientific results from a whole range of disciplines.[11] Secondly, scientific progress has outstripped military affairs and is throwing out new possibilities for weapons development. Thirdly, before the Second World War it was, as a rule, the applied and technical sciences that influenced the development of weapons; but now basic research is coming to have a direct and immediate impact. Fourth, all scientific research is relevant to defense: "now it is impossible to name with firm conviction any branch of natural science which would be neutral or unnecessary for the development of military affairs. Any branch of natural science either already takes part, or can potentially be used in (military affairs)." Fifth, the creation, production, operation and control of modern military equipment is so complex that not only are scientists drawn in to work on military problems, but many officers have to become scientists in their own right.[12]

The "Research-Production Cycle" and the Creation of New Weapons

The R&D effort can best be understood if it is seen in terms of the "research-production cycle." The stages in this cycle can be categorized in various ways; two Soviet definitions are given in Table 1. The differences between these definitions are more apparent than real: Gvishiani classifies mission-oriented basic research as applied research, while Kosov and Popov classify it as basic research; Gvishiani specifies applied research more clearly; Kosov and Popov include assimilation (osvoenie) in the cycle, while Gvishiani omits it.

The "research-production cycle" can form the basis for examining the relationship between the military, science and industry, since the same fundamental processes are involved whether scientific knowledge is being translated into civilian or military production. But some additions to the "research-production cycle" are needed to take account of the role which military requirements play in the creation of new weapons. Cherednichenko writes that

> the creation of new weapons systems includes: scientific research - the appearance of the idea, the formulation of system requirements, analysis of the economic and scientific-technical possibility of creating it; experimental-design work, the manufacture of an experimental model, testing; the organization of mass production, and assimilation into the arsenal.[13]

Here the stage of scientific research is accompanied by the formulation of the military requirement; in some cases the requirement will initiate the research, in others the research will suggest the requirement.

TABLE 1

The "Research-Production Cycle"

A		B	
1	<u>Basic Research</u>	1	<u>Basic Research</u>
		(a)	free
		(b)	special-purpose
2	<u>Applied Research</u>	2	<u>Applied Research</u>
(a)	application-oriented basic research		
(b)	laboratory verification and selection of alternatives		
3	<u>Development</u>	3	<u>Development</u>
(a)	experimental-design work	(a)	experimental-design work
(b)	project-design work	(b)	technological and organizational preparation of production
		(c)	assimilation of production of new products

Sources:

A D. M. Gvishiani, as quoted in Simon Kassel, The Relationship Between Science and the Military in the Soviet Union, R-1457-DDRE/Arpa, Rand Corporation, July 1974, p. 25.

B Ye. V. Kosov, G. Kh. Popov, Upravlenie mezhotraslevymi nauchno-tekhnicheskimi programmami, Moscow, 1972, pp. 9-15.

Before a decision is taken to go ahead with design and development, however, feasibility studies will be done to consider the economic and technological aspects of the proposal. If design and development are approved, experimental-design work will be undertaken and, where appropriate, models prepared and tests made in order to evaluate the design. On this basis a decision will be taken about production. If production is approved, responsibilities will be assigned and the project-technological bureaus will prepare the new production processes. Finally, the Armed Forces will receive the equipment and assimilate it - a process which may entail considerable retraining and reorganization to ensure satisfactory operation and maintenance.

Of course this description is schematic, and the actual process will be more complicated. But it does emerge that there are two main decision points in the process of creating a new weapon: the first is the design and development decision, and the second is the decision to proceed with production. These decision points do not fit into the divisions between basic research, applied research and development. A great deal of applied research will come before the design and development decision, and some may be required afterwards; and some design and development work inevitably follows the production decision.

The military "research-production cycle" has been greatly extended and complicated by the scientific-technical revolution. In the words of one Soviet writer:

> The significant increase in the role of science in strengthening the country's defense has led to a change in the character of the organizational link between it and military affairs. For a long time science and military affairs were related to each other in this way: from military affairs to science and back to military affairs. In military practice a definite requirement arises. At a certain stage this is realized by military specialists and formulated by them as a concrete request which is presented by them to the competent scientific establishments and finds there its solution. With the development of science and the growing complexity of the tasks of strengthening the country's defense, another type of relationship begins to become widespread - from science to military affairs, since modern science is able to find ways of raising the combat capabilities of the army and navy which are new in principle and do not flow directly from the traditional forms of their existence.[14]

The growing role of scientific research has made the formulation of military requirements more complex, for the military planners have to be much more sensitive to, and informed about, the possibilities of technology; and they now have an interest in ensuring that scientific research is directed, in a general way, towards military purposes. This makes the first stage of the cycle and the first decision point - the formulation of a requirement and the initiation of design and development - much more important and much more difficult than before.

The Institutional Framework

Because the information on Soviet military R&D is fragmentary it will be helpful to trace the history of the institutions concerned with the development, production and procurement of arms and materiel. In this way the sparser data for recent years can be most fruitfully interpreted, and the impact of the scientific-technical revolution most clearly assessed. The Armed Forces, defense industry and military R&D establishments conduct their work under the direction and management of the central Party and government bodies. The role of the central Party bodies is of particular importance. The Politburo is the supreme policy-making body; the Central Committee Secretariat has a department for the defense industry and a political department for the Armed Forces; at various times Central Committee secretaries have had responsibility for defense policy and the defense industry.[15] There is no need to outline the nature of Party direction and management here, but mention must be made of the specialist central bodies for defense policy-making.

A. Central defense policy-making bodies

The present formal structure of the defense policy-making bodies bears a marked similarity to that which existed in the late 1930s. At that time major questions of defense policy were decided in the Defense Committee attached to the U.S.S.R. Council of People's Commissars (Sovnarkom).[16] This Committee, which had been created in April 1937, was supplemented in January 1938 by a permanent Military-Industrial Commission (Voenno-promyshlennaya komissiya) which had the task "of mobilizing and preparing industry, both defense and non-defense, to secure completely the fulfillment of the plans and assignments of the Defense Committee for the production and delivery of arms to the RKKA and the People's Commissariat of the Navy."[17] Within the Defense Commissariat major decisions were taken by the Main Military Council (Glavnyi Voenny Sovet) of the Red Army, which was formed in March 1938. (In December 1937 a separate Naval Commissariat had been established, and in March 1938 a Main Military Council was created there too.)[18] This Council consisted of the People's Commissar (Narkom), his deputies and one member of the Politburo, although the most important decisions were taken with Stalin and other members of the Politburo present.[19] In practice no decision was taken without Stalin's participation; if he was not present at a meeting, the decisions were forwarded to him for approval.[20]

Both of these bodies were superseded during the War. On June 30, 1941, the State Defense Committee (GKO) was set up, with all the power in the state in its hands.[21] The Main Military Council of the Defense Commissariat, which acted as chief command organ for the first day of the War, was eventually transformed into the General Headquarters of the Supreme Command (Stavka Verkhovnogo Komandovaniya).[22] In September 1945 the GKO was abolished and the Sovnarkom assumed its former role (although there is no evidence that the Defense Committee was reestablished).[23] In January 1946 the Politburo decided to combine the Defense and Naval Commissariats, and a Higher Military

Council (Vysshii Voennyi Sovet) was formed in the new Commissariat in place of the Stavka. This was "the collegial body which had existed before the war," and consisted of members of the Politburo and Central Committee and leaders of the Armed Forces.[24] In March 1950 the Ministry of the Armed Forces was split once again into two Ministries. Main Military Councils were now created in these Ministries, while the Higher Military Council was moved upwards and attached to the Council of Ministers, apparently with reduced military representation.[25] The Main Military Council of the Ministry of Defense (reunified in 1953) appears still to exist.[26] The Higher Military Council seems to have survived into the 1960s, but at some point it was replaced by, or renamed, the Defense Council (Sovet Oberony).[27] It has recently been revealed that Brezhnev is Chairman of this body, and that it concerns itself with "questions of military development (voennoe stroitel'stvo) and of strengthening the might and combat readiness of the Soviet Armed Forces," i.e. with military policy and defense production.[28] The Defense Council appears to be attached to neither the Politburo nor the Council of Ministers. In 1972 it became known that there exists a Military-Industrial Commission, headed by L. V. Smirnov, one of the Deputy Chairmen of the Council of Ministers.[29] This Commission may occupy a position similar to its prewar namesake.

B. The Defense Industry

One of the main aims of Soviet industrialization was to provide the Red Army with modern military equipment. The first Five Year Plans for economic development were accompanied by Five Year Plans for the development of the Red Army (plany stroitel'stva Krasnoi Armii).[30] During the 1930s the defense industry grew to meet the Red Army's needs. In December 1936 a special Defense Industry Commissariat (NKOP) was created, with four main administrations (glavki) for aircraft, armament, ammunition and shipbuilding.[31] In January 1939 the NKOP was dissolved and four new Commissariats were created on the basis of the former glavki. Each of the new Commissariats had its own administrations, construction trusts, design organizations, higher and secondary educational establishments, and factory trade schools.[32] Not all defense production was undertaken by these Commissariats; with the growing prospect of war the various machine-building commissariats turned increasingly to the production of weapons.[33] In 1937 defense production received about 30 per cent of all budget allocations for capital investment and working capital in industry; the proportion rose to 40-50 per cent in 1939-41.[34] As the defense sector grew it became more difficult to manage. In April 1940 the Economic Council (Ekonomsovet) of the U.S.S.R. Sovnarkom was reorganized and several councils set up for the main branches of the economy. One of these was the Economic Council of the Defense Industry (Khozyaistvennyi sovet oboronnoi promyshlennosti) which had the task of directing all productive activity geared to the needs of the country's defense.[35]

During World War II the branch structure of the defense industries was retained, and two new Commissariats were created: for the Tank Industry (September 1941) and for the Mortar Industry (November

1941).[36] The defense industries came under the direct control of the State Defense Committee (GKO), some members of which assumed responsibility for different branches: Beria for armament and ammunition, Malenkov for aircraft and aeroengines, Molotov for tanks, Mikoyan for fuel and stores, Kaganovich for rail transport. These GKO members coordinated the needs of the front with military production capacity, and under their direction the Commissariats compiled their plans.[37] The GKO created special committees and commissions as it saw fit, and exercised control over military production not only through the government apparatus, but also through party organizations and a network of GKO plenipotentiaries (upolnomochenniye).[38]

By 1944 the production of military equipment was already being reduced to make way for civilian goods. The Medium Machine- Building and Mortar Industries were instructed to turn out agricultural machinery, while the Chemical and Ferrous Metallurgy Industries were ordered to produce fertilizers. In May 1945 the GKO issued a decree on the conversion of industry from military to civilian production. Some enterprises went over completely to civilian production, but many continued to turn out some military goods.[39] The process of conversion was accompanied by a reorganization of the defense industry: enterprises were regrouped and some Commissariats changed their names.[40]

The transition from wartime to peacetime was not accomplished without difficulty. During the War little preparation had been made for conversion to civilian production.[41] In many cases conversion required new production processes, new machinery, the elimination of bottlenecks and the retraining of workers.[42] One of the main difficulties was created by the much more complex nomenclature (nomenklatura) of output that the peacetime economy needed. Thus the plants of the tank industry which during the War had had seven or eight basic types of output, in 1946 had to adjust to the series production of more than forty basic types of locomotive, wagon and transport machinery. As a consequence productivity fell, and the workers had to be retrained.[43] In 1946, as a result of the sharp drop in military production and of the difficulties of conversion, the gross output of industry was seventeen per cent lower than in 1945. Only in 1947 did sustained rapid growth begin again.[44]

The next major reorganization of the defense industry came in 1953 and 1954. The defense sector did not escape the formation of super-ministries immediately after Stalin's death, but these were disbanded by April 1954.[45] At the same time two new ministries were set up with defense production responsibilities: in June 1953 the Ministry of Medium Machine-Building took over the nuclear program which had hitherto been administered directly by the U.S.S.R. Council of Ministers, and in January 1954 the Ministry of the Radiotechnical Industry was established.[46] In April 1955 a Ministry of General Machine-Building was created; this seems to have taken over the production of conventional weapons which had been the responsibility of various machine-building ministries, but in May 1957 it was absorbed into the Ministry of the Defense Industry.[47]

Between 1957 and 1965 the defense industry, like the rest of the

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Soviet economy, underwent a number of confusing reorganizations; but it is important to note that the defense sector was treated differently from the rest of the economy. The Law of May 10, 1957 disbanded most industrial ministries and assigned their plants to the new regional sovnarkhozy. The Ministries of the Aviation, Defense, Radiotechnical, Shipbuilding Industries and the Ministry of Medium Machine-Building were not disbanded, although their plants were to be planned through the sovnarkhozy. In December, however, all of these ministries, except that for Medium Machine-Building, were converted into State Committees which retained central control of R&D and the introduction of new technology.[48]

When the Supreme Council of the Economy (VSNKh) was set up in 1963 some State Committees - including those for the defense industry - were placed directly under the VSNKh rather than under Gosplan; these State Committees seem to have regained plant-management and production responsibilities.[49] In March 1965, six months before the major economic reform, six State Committees were formed into Ministries: Aviation, Defense, Radioelectronics, Shipbuilding, Medium Machine-Building (which had been made a State Production Committee in March 1963) and Electronics (the State Committee for which had been set up in March 1961).[50] At the same time the Ministry of General Machine-Building was formed, with responsibility for missile production.[51] In February 1968 the Ministry of Machine-Building was created, apparently for the production of ammunition.[52] In 1974 the Ministry of Communication Equipment was established separately from the Ministry of the Radio Industry.

It will be clear from this outline of its development that the Soviet defense industry forms a separate sector in the Soviet economy. Of course not all its output is military; for example, it produces civil aircraft, merchant ships and consumer durables. In 1971 Brezhnev declared that "42 per cent of the entire volume of the defense industry's production is for civilian purposes."[53] Not all the rest need go to the Ministry of Defense, since the 58 per cent may cover production for strategic reserves, the Frontier Guards, KGB and MVD troops, and for export. At the same time some military equipment is produced by enterprises outside the defense industry: for example, trucks by the Automobile Industry, and fuel and chemical warfare agents by the Chemical Industry.[54]

Because of its scope and complexity the activities of the defense industry have required some form of direction and coordination at the Council of Ministers level. Before the War the Military-Industrial Commission and the Economic Council of the Defense Industry had functions of this kind, and their responsibilities extended to all defense production, no matter in which branch it took place. During the War the GKO exercised direct control, and after the War the practice of making individual leaders responsible for particular areas of defense production seems to have continued.[55] At the same time special agencies were created within the Council of Ministers to manage the nuclear weapons and missile development programs.[56] Since the mid-1950s a special body under the Council of Ministers has had general responsibility for the defense industry. From 1957 to 1963 this was headed by D. F. Ustinov; and since 1963 by L. V. Smirnov.[57]

There exists in the defense sector (as in other branches of Soviet industry) a very powerful tendency towards ministerial autarky: the pursuit of autonomy through the creation of supply industries under the Ministry's own control. In the 1930s the defense industrial Commissariats had their own metallurgical base, and by the end of the decade they were responsible for about 20 per cent of steel output and between 17 and 20 per cent of machine-tool production.[58] In the early 1960s the Aviation Industry was reported to have plants for producing sheet aluminum and magnesium alloys, shaped metal and plastic and rubber products. Over 90 per cent of all aviation production (airframes, aeroengines, instruments, avionics) was concentrated in the Ministry's enterprises.[59] It seems that all branches of the defense industry manufacture their own instruments.[60] But the pattern of concentration is not uniform. Before the War the twenty-one plants of the Shipbuilding Industry cooperated with more than two hundred factories of other industrial branches.[61] When the Ministry of General Machine-Building was set up in 1965 the plants engaged in missile production were removed from the Ministry of the Aviation Industry. But the metallurgical plants which produce the light alloy rolled stock which is needed in missile production have remained under the Ministry of the Aviation Industry; moreover, the new Ministry succeeded in gaining control of only part of the missile electronics programs (the rest are under the control of the Ministry of the Radiotechnical Industry).[62]

As part of Soviet industry the defense sector is subject to central planning and management, and its Ministries are organized in the same way as other industrial Ministries.[63] At the same time, however, there are important differences in the internal arrangements of the defense sector. Many of these relate to the role the Ministry of Defense plays in supervising military production, and will be examined later; but some of the defense industry's special features can be pointed to here. The defense sector has first priority in the allocation of materials or parts which are in short supply.[64] Engineering-technical personnel in the defense sector are better paid than those in civilian industry, and, by and large, the workers also receive higher wages than in civilian production.[65] It does not follow, however, that the quality of personnel is in fact higher, for many scientists and engineers, in particular those who seek recognition through publication of their work, find the secrecy stultifying and are thus not attracted by the higher pay. The secrecy which prevails in the defense sector makes it easier to gain higher degrees, and so qualifications are not necessarily a good indication of quality. Furthermore, the benefits which the defense industry can offer to employees - in housing and medical care, for example - are now less attractive than they used to be.[66] Consequently the priority position of the defense industry does not automatically guarantee that it receives the best workers and R&D personnel.

The legal and accounting relationships in the defense sector are different from those in the rest of the economy. Their distinctiveness consists in:

less control by the bank and budgetary financial organs over the economic activity of the enterprise, in direct financing by superior agencies, without the use of bank credit. The relations between customer and supplier are regulated not only by economic contracts, but also by allocation certificates (naryadyzakazy) from the appropriate agencies.

Not all the enterprises which serve the defense sphere have sources for paying funds into the state budget. Before the transition of the new system of planning and economic management, the main source for accumulation and for the formation of incentive funds was the saving made from lowering the average cost price (sebestoimost') of defense production and the profit made from the production of those commodities which were sold outside the defense sphere. The plan of the volume and the basic assortment of the output of defense industry enterprises is determined by superior bodies as an appropriate command, which it is obligatory to fulfil precisely.[67]

This indicates that before the 1966-67 price reform no planned profit or turnover tax was included in the price of military goods, so that these goods were sold at cost price; planned profit seems not to be included. It suggests, also, direct and specific central management of defense production, with financial control playing a nugatory role. It appears, for example, that the missile output of the enterprises of the Ministry of General Machine-Building is regulated by decrees (postanovleniya) from the Council of Ministers. These can be issued at any time and are not constrained by existing state plans.[68]

The defense industry forms a distinct sector in the Soviet economy, with its own specific features. It does not seem, however, that the creation of a separate arms economy has been a conscious goal of policy. The tendency towards separation appears to be a by-product of the Soviet effort to create mechanisms for extracting resources from the whole economy and applying them as effectively as possible to military purposes.[69]

C. The R&D Establishments

Military R&D is carried on in three different types of establishment. The research institutes and design bureaus of the defense industrial Ministries concentrate on applied research and development. The Academies of Sciences and the VUZy engage mainly in basic research. The research institutes and academies of the Ministry of Defense focus on theoretical and applied research with a specific military-operational orientation. These distinctions do not hold rigidly, since it has been Soviet practice in high priority areas to set up special-purpose organizations and programs which cut across interdepartmental boundaries.[70]

Each of the Ministries in the defense industry has under its control central research institutes which engage in applied research in their branch's field, and a network of design bureaus which design and develop new weapons and new production processes. The work of these establishments is planned, directed and supervised by the Technical Administration of the Ministry. These R&D establishments are largely financed from the State Budget and do not operate on a khozraschot basis.[71]

The organization of these R&D establishments may vary from one branch to another. In tank and artillery development the design bureaus are attached to production plants, where they may have experimental shops at their disposal.[72] In the Shipbuilding Industry the shipyards have their own design bureaus, but there may exist central design bureaus as well, for there is ample evidence of firm central control in the design of ships.[73] In the Aviation Industry experimental-design bureaus (opytno-konstruktorskie byuro) exist as relatively autonomous organizations with their own experimental factories which can produce prototypes.[74] In aviation and missile production the design bureaus play a crucial role (which accords well with the publicity designers receive), for all production plants are assigned to one or other design bureaus.[75] The decrees of the Council of Ministers which regulate production in the Ministry of General Machine-Building are in effect government ratifications of contracts concluded between the Ministry of Defense and the design bureau. These decrees stipulate the dates for experimental and series production, specify the subcontractors, assign funds for each part of the work, and make an individual responsible for fulfillment of each part.[76] This is not to say, however, that the design bureaus are free agents, for their design and development work is regulated by the Ministry which allocates materials and lays down norms for their use, and by the branch research institutes which provide guidelines and procedures for design.[77] The constraints under which the design bureaus work encourages commonality (the use of standardized parts and subsystems), which is one of the design features that can be discerned in Soviet weapons.[78] At the same time the subordination of production plants to design bureaus helps to account for the element of redundancy in Soviet military production: not only are parallel and competing designs drawn up, but they are also put into production (see the SS-17 and SS-19 ICBMs, and the MiG-23 and Su-17/20 tactical fighter aircraft).[79]

The second sector in which military R&D is conducted is the network of research institutes, academies and higher educational establishments of the Ministry of Defense. In the pre-war years the research institutes appear to have played an important role in some areas of weapons development. For example, the Communications Research Institutes of the Army and Navy (NIISKA and NIIS VMF) played a role in the development of radiotechnology and radar.[80] Little is known of the present organization or work of the Ministry of Defense's research institutes; the available evidence suggests that they do not play a major role in military R&D. The research institutes, like the academies and to a lesser extent the VUZy, appear to concentrate on those areas most immediately relevant to the definition of military requirements and to the employment of equipment when it is delivered. The main preoccupations of the Ministry of Defense's network seem to be: strategic, operational and tactical questions; research in such applied fields as ballistics, navigation, control theory; keeping abreast of foreign science and technology; forecasting the development of weapons and forces.[81]

Before 1941 the institutions of the U.S.S.R. Academy of Sciences were involved in military R&D only to the extent of giving scientific advice on technical questions.[82] After the German invasion the Academy set itself the task of making practical use of scientific research, and its establishments began to work on the development of new weapons, ammunition and fuel.[83] Most of this research was concerned with specific problems, for example: the development of fire control equipment (I. S. Bruk), the elimination of flutter on aircraft at high speed (M. V. Keldysh), the development of subcalibre tank projectiles (N. T. Gudtsov) etc.[84] Commissions were set up by the Academy for many important areas of research; among them were: the Scientific and Technical Problems of the Navy, Anti-Tank Weapons, Military Geography.[85]

Towards the end of the War the U.S.S.R. Academy of Sciences drew up recommendations for scientific research in peacetime. Among the areas given particular importance were: the study of nuclear reactions and intra-atomic energy, semiconductors, electronics, radar, polymers, calculating machines, jet technology, the theory of combustion, etc. These recommendations (which have a clear military element) were used in compiling the plans for the Academy's post-war work.[86] The importance of close cooperation with industry was stressed in these plans.[87] The Academy may well have had a role in military R&D for the "traditional" defense industries, but its most important military work was in the development of advanced technologies. In the summer of 1943 a special laboratory had been created in the Academy to work on the development of the atomic bomb. This later became the (Kurchatov) Institute of Atomic Energy and remained part of the Academy until 1961.[88] In 1951 the Institute of Radioengineering and Electronics was set up at the instigation of Academician A. I. Berg, who also has the military rank of Engineer-Vice-Admiral. In 1953 Berg left the Institute to become Deputy Minister of Defense for Radar and Radioengineering (a position he held until November 1957). In 1961 this Institute too was removed from the Academy system.[89] Where an institutional base for R&D already existed - as in aviation, shipbuilding and even in missile development - the role of the Academy appears to have been less important.

The reform of 1961 redefined the Academy's role as primarily that of basic research; in 1963 the mission-oriented nature of basic research was re-emphasized and the Academy given responsibility for pointing out the technological possibilities of fundamental research.[90] (Some technologically-oriented institutes in the Academy system have their own design bureaus and experimental production facilities.)[91] In spite of the removal from the Academy of some important institutes in the early 1960s, (in line with the change in policy) the Academy's role in military R&D has not ended. It has been shown clearly that basic research of military relevance is conducted in the Academy's institutes.

For example, work on high-energy gas dynamic lasers, optical plasmatrons and high-current charged particle beams is done at the Lebedev Physics Institute, the Institute of the Problems of Mechanics of the U.S.S.R. Academy, the Physico-technical Institute of the Ukrainian Academy, and the Institute of Theoretical and Applied Mechanics of the Siberian Division of the U.S.S.R. Academy.[92] It thus appears that one of the main features of military R&D since the War has been the involvement of the Academies of Sciences. At first the U.S.S.R. Academy helped to foster new science-based technologies; since the early 1960s it has concentrated on basic research and a small number of very advanced technologies. But since basic research is acknowledged to be an increasingly important element in military R&D, the Academy's role may be growing rather than diminishing.[93]

D. The Armed Forces

If military production is to be coordinated with industrial production as a whole, long-term plans have to be prepared for the development of the Armed Forces. The prewar Five Year Plans for military development have already been mentioned. Long-term plans (from 5 to 20 years) are still drawn up. These determine the numbers and types of equipment to be acquired, changes in the organizational structure of the Armed Forces, the missions and roles of the Armed Forces in war, the creation of stocks of arms, materiel, and other stores, and the training of reserves and command personnel.[94] But just as the economic plans do not lay down a rigid and immutable policy, so too the long-term plans for military development can be changed if circumstances require it. In the 1930s many important military production decisions were taken outside the framework of the plan;[95] Sokolovskii suggests that new plans may be called for by technological developments or changes in the international situation;[96] and, as has been seen, orders for the production of strategic missiles are not bound by the State economic plans.

The first Five Year Plans for the development of the Red Army were drawn up by the Staff of the RKKA (from 1935 the General Staff) on the basis of guidelines laid down by the Central Committee and the Sovnarkom. The initial work for the plan was done by the administrations of the central apparatus of the Defense Commissariat and was then coordinated by the RKKA Staff. This plan was confirmed by the Revvoensovet in 1928, but, under pressure from the Politburo, was greatly revised between 1928 and 1931, with an increase in its targets and control figures.[97] It is probable that a similar planning process exists today: the political leadership will give guidelines for the development of the Armed Forces; the General Staff will coordinate the plans and reconcile the claims of the different branches of the Armed Forces and main administrations of the Ministry of Defense; the Main Military Council (or a collegial body in the Ministry) will review the plans; and a final decision will be reached by the Politburo before implementation.[98] This process will naturally involve continuous consultation and iteration.

Military development cannot be isolated from economic planning:

Coordinating the planning and development of the Armed Forces with military production in the national economy has exceptionally great significance. The appropriate military bodies, together with the agencies of national economic leadership, work out the principles of a unified military-economic and military-technical policy, coordinate the plans for rearmament and material-technical supply with the plans for the delivery of output by industry and so on. In this the military bodies concentrate their attention on presenting orders to the national economy in good time, on control (kontrol') over the course of fulfillment of the orders, and - in the event of a change in requirements - on rapid correction of the orders.[99]

Military requirements must be matched to productive capacity. Military production has been planned and managed by specialist bodies at the Council of Ministers level; presumably the Ministry of Defense and the General Staff now work with the Military-Industrial Commission in drawing up the plans for military production. Sheren suggests that this Commission "might be composed of representatives of the defense-industrial Ministries, the Ministry of Defense, and any other organization concerned with military research, development, testing and production."[100] The role of the military in this process is to place orders and to supervise production. The Military-Industrial Commission will have to see if the military requirements can be met with the resources available to them. They will have to coordinate their plans for military production with the work of the central planning agencies such as Gosplan.[101]

It is the General Staff and a collegial body of the Ministry of Defense which draw up and approve the plans for military development (subject of course to central Party direction and ratification). But it is a notable feature of Soviet military organization that special agencies have been set up within the Ministry of Defense or General Staff to handle major re-equipment programs. In November 1929, the post of Chief of Armament (nachal'nik vooruzheniya) was created to help carry through the technical reconstruction of the Red Army. The Chief had four administrations (Artillery, Chemical, Signals and Telemechanics) under him, although the actual scope of his influence and activity was much wider than the names of these administrations might suggest.[102] Tukhachevskii, who held the post from 1931 to 1936, had an important role in the development of air and tank forces in the Red Army.[103] The Chief of Armament's apparatus was in effect a technical staff which worked closely with the RKKA Staff and played a major part in the policy of rearmament.[104]

In 1936 the post of Chief of Armament was abolished and his functions were given to the newly created Main Administration of Armament and Technical Supply (Glavnoe upravlenie vooruzheniya i tekhnicheskogo snabzheniya) which had three departments (mobilization-planning, standardization, inventions) and a technical inspectorate. Although subordinate to the Defense Commissariat, it worked in practice in accordance with General Staff directives. The functions of this Main Administration were: to supervise the realization of armament plans; to develop and coordinate the plans for research, design and invention work in the field of armament and technical supply; to take stock of the provision of arms and materiel to the Red Army on mobilization; to inspect the condition, exploitation and storing of arms.[105] This Main Administration had vanished by June 1941. In the months immediately before the German invasion its responsibilities appear to have been shared by several different bodies, including the Main Artillery Administration, the Main Armor Administration and the Bureau of Inventions.[106]

Since the War the post of Deputy Minister for Armament has existed twice: in the late 1940s and early 1950s, and again since November 1970; and from 1953 to November 1957 there was a Deputy Minister for Radar and Radioengineering.[107] The precise responsibilities of these Deputy Ministers is not known, but presumably they included the supervision of development and production programs, and the assimilation of arms and materiel into the Armed Forces. The first Deputy Minister for Armament was Marshal of Artillery N. D. Yakovlev, who was chief of the Main Artillery Administration from 1941 to 1948; then came Chief Marshal of Artillery M. I. Nedelin, who commanded the missile troops from 1945 to his death in 1960 (in this time they were transformed from an experimental unit into the Strategic Missile Forces).[108] The present holder of the position is Colonel-General N. N. Alekseev, who was Chairman of the General Staff's Scientific-Technical Committee from 1960 to 1970; and from 1955 to1958 he had been in "responsible work" in the Council of Ministers.[109] The Deputy Minister for Radar and Radioengineering was Engineer-Admiral Academician A. I. Berg, whose role in radar development has already been referred to. Lower-level bodies with procurement and (some) R&D responsibilities have existed throughout the postwar period: the Navy has a Main Administration of Shipbuilding and Armament, while the Ground Forces have the Main Missile and Artillery Admnistration, and the Air Force has a similar agency.[110]

The Ministry of Defense occupies a very special position in the formulation and management of military-technical policy. It not only orders the arms and materiel, but also supervises their production. This gives the Ministry a kind of consumer sovereignty - the ability to impose its wishes on the production process - which does not exist elsewhere in the Soviet economy. The degree of control the Ministry exercises can be illustrated by examining the part it plays at the various stages of weapons design and production.

The Ministry of Defense either initiates or approves the proposal for a new weapons system and lays down the general performance parameters that it requires. Designs are prepared by the design bureaus and submitted to the Ministry, which selects those that are to go ahead to development.[111] A special body in the Ministry checks the specifications and makes sure that some general conditions are met - for example, vibration stability, ability to perform in certain climatic conditions, and perhaps also protection against nuclear weapons effects.[112] When a model or prototype is prepared it will undergo factory tests (in which the military representatives take part) and troop trials.[113] A State Commission, usually headed by an officer, will check that all the specifications have been fully met.[114] If the design is approved for production (decisions not to produce or to modify can be taken) a contract will be concluded with the design bureau. In this decision process the Ministry of Defense may rely heavily on outside scientific and technical advice, and will have to obtain Party and Council of Ministers approval and ratification for its decisions; but it is clear that the degree of supervision exercised by the customer is very great indeed.[115]

After the production decision the design bureau will prepare the documentation for its enterprises; and no change may be made in the design without the approval of the design bureau.[116] Project-technological bureaus and branch research institutes will prepare the appropriate new production processes. The transition from development to production is an extremely important stage in the "research-production cycle." In the words of one Soviet source:

> The high quality of weapons is ensured by careful finishing-off (otrabotka) of the designs and testing of prototypes, by the compilation of good technical documentation, by the development of a rational technological process and the organization of well-ordered (nalazhennyi) series production.[117]

But the effort to ensure a high quality of armament does not end here. Since the 1930s (at least), a group of military representatives (voennye predstaviteli) has been assigned to each of the plants engaged in military production.[118] This group consists of military engineers, technicians and office personnel. In the larger plants "the commander of the military team is a field grade officer equal in experience and status to the plant manager."[119] The voenpredy exercise strict quality control throughout the production process. They are paid by the Ministry of Defense and, unlike the departments of technical control (otdely tekhnicheskogo kontrolya) in civilian industry, have no material interest in the factory's plan fulfillment; hence they have no incentive to accept defective goods.[120] Moreover, the quality standards enforced in military production are higher than those in civilian industry. It has been reported that even for the same goods three different standards are enforced: for defense, for export, and for "common" domestic use.[121] The voenpredy are apparently quite willing to exercise their power to refuse goods which do not meet specification.[122]

The Science Policy and the Management of Military R&D

Since the end of the War, and in particular since 1955, the effort to stimulate technological progress has grown in importance as an area of government activity in the Soviet Union. Special science policy agencies have been set up with responsibility for the management of R&D. The emphasis of these agencies' work has shifted from the latter to the earlier stages of the "research-production cycle," in part because of the need to establish a satisfactory division of labor with the branch Ministries. The industrial Ministries have been responsible for the introduction of new technology, and have resisted outside interference. It is no accident that the major effort to coordinate R&D came in the period 1957-65 when the Ministries were no longer in existence.[123]

The military role of the science policy agencies can best be explored if the development of those agencies is traced and earlier approaches to the planning of military R&D outlined. Although science policy has grown more important in the last twenty years, the planning of military R&D is not a recent phenomenon. At the end of 1937 a plan was drawn up which aimed at the creation of modern armament by developing new models and modernizing the most promising old systems. This plan seems to have stimulated the development of the R&D base: "In the basic leading enterprises there grew up powerful experimental shops and design bureaus, and research institutes were strengthened."[124] In 1938 the Main Artillery Administration (GAU) of the NKO had 60 million rubles to spend on research, and in 1939 it had 92 million. This amounted to about one per cent of the total value of GAU's orders for equipment (which in turn constituted about 20 per cent of the defense budget).[125]

During the Great Patriotic War a Technical Council was attached to the State Defense Committee. This Council, which had various specialist sections, seems to have supervised and coordinated R&D. In September 1941, for example, it discussed and approved the Academy of Sciences' plan for defense work.[126] Other councils were created for more specialized fields. On 10 July 1941 a Scientific-Technical Council for Chemical Problems connected with Defense was set up under the State Defense Committee.[127] In 1943 a Council (later Committee) on Radar was established. This had responsibility for expanding research on ultra-high frequencies, organizing an industrial base, training personnel and creating a radar system for the Army and Navy. Malenkov was the Council's first Chairman, and A. I. Berg his deputy; M. Z. Saburov succeeded as Chairman in 1947.[128] The NKO maintained contact with the Academy of Sciences through Colonel-General A. V. Khrulyev who, besides being Chief of the Rear, was head of the Commissariat's Scientific-Technical Administration. Some military specialists took part in the Academy's work.[129]

Since the end of the War the management of military R&D has become more complex. Before the War, weapons development does not seem to have included research in any systematic way. The process of development was most commonly initiated by the formulation of a military requirement which the designers then tried to meet within the existing state of the art. After tests a production decision was made. With the growing dependence of weapons development on scientific research, a new element was brought into the relationship between science and military affairs. There is, however, no evidence of a unified military R&D policy in the immediate post-war years: the most important areas of advanced technology were handled by specialized bodies. The Committee on Radar remained in being; in 1945 special agencies were set up in the Sovnarkom and the Armed Forces to manage the atomic bomb and missile development programs;[130] in December 1945 a plan for aviation R&D was adopted after extensive discussions in the Central Committee and the Government.[131]

The late 1940s saw the first attempt to create a special institution to carry out a national technical policy. This was the State Committee for the Introduction of New Technology into the National Economy (Gosudarstvennyi komitet vnedreniya novoi tekhniki v narodnoe khozyaistovo, or Gostekhnika), which was set up in December 1947 and remained in existence until February 1951.[132] It was headed by V. A. Malyshev, a Deputy Chairman of the Council of Ministers and one of the leading industrial managers. Malyshev had been Commissar for Heavy Industry and for the Tank Industry, had played an important role in the early stages of the atomic bomb project, and was to take over the Ministry of Shipbuilding Industry in January 1950 when it was embarking on a ten-year warship-construction program.[133] The responsibilities laid on the Committee were extensive: "the forced introduction of new technology into the national economy with the aim of further accelerating the technological arming and rearming of the U.S.S.R. national economy."[134] But Gostekhnika's actual work is not clear. The short lifetime of the Committee - three years, and only two with Malyshev as full-time Chairman - suggests either that it was ineffective in performing its general role (even though the first annual plan for the introduction of new technology was approved in 1949), or that its general responsibilities hid a quite specific task which it completed successfully. There is, however, no evidence to support the latter conclusion.

By the early 1950s new industrial Ministries had been created for nuclear weapons and radiotechnical equipment. In March 1955 Malyshev, who was still Deputy Chairman of the Council of Ministers, moved from his position as Minister of Medium Machine-Building to be "entrusted in the U.S.S.R. Council of Ministers with the responsibility of leading a group of ministries concerned with machine-building" (this latter term might have indicated the defense sector).[135] In May Malyshev was appointed head of the new Gostekhnika. Whether the March and May appointments were in fact the same is not clear; if they were different, Malyshev may have been succeeded by Khrunichev, who had been his first deputy at the Ministry of Medium Machine-Building and had been made Deputy Chairman of the Council of Ministers in February. In December 1956 Malyshev became First Deputy Chairman, and Khrunichev Deputy Chairman, of Gosekonomkommissiya, and both lost the rank of Deputy Chairman of the Council of Ministers. Malyshev remained Chairman of Gostekhnika until his death in February 1957.[136]

1955 marked a turning-point in Soviet science policy. The July Plenary Session of the Central Committee indicated how seriously the leadership took the problem of technological innovation, while the new Gostekhnika was the first of an unbroken series of science policy bodies. The military function of these institutions is not known, but it is possible to suggest what it may have been. As the emphasis of their work has moved towards the earlier stages of the "research-production cycle," it is probable that their role has become more significant for the defense sector. This is because they have acquired increasing responsibility for services and functions which have not traditionally been performed by the defense industry but have nonetheless become more important for its work. It is unlikely that the defense industrial Ministries would allow control over the later stages of the "research-production cycle" to pass from their hands. But they are likely to have found some of the functions of the science policy bodies increasingly relevant: the coordination of basic research in the Academy system; the provision of scientific and technical information; the study of foreign science and technology; the forecasting of developments in science and technology.[137]

The close ties between Malyshev and Khrunichev, and their background in the defense industry, suggests that Gostekhnika might have had some military responsibilities between 1955 and 1957. But, for a variety of reasons, the military role of Gostekhnika's successor - the State Scientific-Technical Committee (1957-1961) - was probably very limited.[138] From 1957 to 1965 military R&D was organized differently from civilian R&D. With the transformation of the defense industrial Ministries into State Committees in December 1957, Ustinov became Deputy Chairman of the Council of Ministers with responsibility for the defense industry as a whole; and the primary activity of the State Committees for which Ustinov was responsible was the planning and management of R&D. At the XXI Party Congress Ustinov devoted much of his speech to the successes of technological innovation in the space program.[139]

The State Committee for the Coordination of Scientific Research (GKKNIR), which was set up in 1961, had wider power than its predecessors. It could decide on the most important research projects and assign research institutes to work for them. It had special responsibility for "complex" and inter-branch programs.[140] Khrunichev and Rudnev, its two Chairmen between 1961 and 1965, were leading defense industry managers. The same reasons for supposing that the State Scientific-Technical Committee had a limited military role apply here too. But with the growth of the Committees' powers and responsibilities in the earlier stages of the "research-production cycle," their usefulness to the defense sector might also have increased. In 1965, in line with the reform of the system of economic planning and management, the GKKNIR was transformed into the State Committee for Science and Technology. This was given wide powers and the task of ensuring a "unified state policy" in the field of scientific-technical progress and in the utilization of scientific and technological achievements in the economy.[141]

None of the leaders of the State Committee for Science and Technology are men with experience in the defense industry, and it has been reported that the Committee does not have responsibility for reviewing the budgets for R&D in defense, space or atomic energy.[142] This does not mean, however, that the Committee has no military function.[143] As has been seen, much research of military importance is done in the "civilian" sector, and it seems likely that the State Committee has a role in fostering and directing research of military interest, and in drawing military attention to promising lines of research. What is not clear, however, is whether the State Committee has any responsibility for coordinating military interbranch R&D programs. It seems likely that if institutes are engaged in military work, at some stage that work will come under the control of a military or military-production body.

There are many gaps in the history of Soviet science policy organization; but this outline suggests that although the military "research-production cycle" has been made more complex by the growing importance of basic research, this new element in the cycle has not been brought under the direct administrative control of the Ministry of Defense or of the defense industry. This is not to say, however, that the Ministry of Defense plays no role in planning and directing research outside the defense sector. The Ministry has a network of scientific-technical committees which provide advice on proposals for new weapons,[144] and perhaps also on the promising directions of scientific research. Although special agencies may be set up for some programs, coordination between the defense sector and the research institutes in the Academy system is probably effected at the Council of Ministers level, with the State Committee incorporating into its plans the requirements of the Ministry of Defense and the Military-Industrial Commission. It is possible that continuous consultation takes place between the State Committee's advisory apparatus and the Ministry of Defense and defense industrial Ministries.

The Management of Military Technical Policy

The analysis so far makes it clear that the Ministry of Defense and the General Staff play a major role in the management of the military "research-production cycle." As technological progress has become more important in defense, the military leaders have paid increasing attention to the management of innovation. Marshal Grechko has written that a "unified military-technical policy" (edinaya voenno-tekhnicheskaya politika) is one of the chief ways of stimulating technological progress and ensuring that military equipment is "on the level of modern requirements."[145] He has defined the goals of such a policy as follows:

> A unified military-technical policy is called on to secure the favourable development of those directions of scientific-technical progress in the military field which are capable most fully and comprehensively of satisfying the growing requirements of the defense of the U.S.S.R. for effective means of conducting modern military actions. Along with the solution of current questions it orients scientific-technical cadres to the working-out of different long-term problems, the results of which can find wide application in military affairs in the future. Of particular significance are fundamental research aimed at the discovery of as yet unknown properties of matter, phenomena and laws of nature, and the development of new methods of studying and

using these for strengthening the state's defense capability.

... A unified military-technical policy ought to ensure the union of industry with science in the interests of creating such models of weapons and military equipment as will not become obsolete for a long time, will be highly effective; that is, so that every type of weapon and military equipment, with the least expenditure on its development, production and exploitation, will possess the highest tactical-technical possibilities, in the first place powerful strike characteristics.

... The object of a unified military-technical policy is to see to the rational improvement of the weapons and combat materiel of all services of the Armed Forces and all arms of service in accordance with their role and mission in modern war. In this it is extremely important to penetrate into the laws (zakonomernosti) of development of military affairs, to study the basic directions for using the achievements of scientific-technical progress abroad, to take account of the tendencies of development of weapons and combat materiel.[146]

Grechko points to two further goals of military-technical policy: a reduction in the element of physical labor in military work through mechanization and automation; and an improvement in the methods of troop control. For the purposes of this paper Grechko's statement is interesting because it indicates the wide range of military-technical policy objectives: the direction of fundamental researchto military purposes, the stimulation of technological innovation, but with due regard to cost; the analysis of the development of armed forces and their armament and roles, with particular attention to foreign military technology.

The "scientific-technical revolution" has made the management of technological innovation in the defense sector not only more important but also more difficult. In the words of Cherednichenko:

> The definition of the state's military-technical policy constitutes today a complex scientific problem. The task consists of ensuring the constant high combat preparedness and combat readiness of the Soviet Armed Forces with the maximum optimization of costs. The choice and creation of the most appropriate, effective, promising (perspective) and economic system of armament are assuming primary importance. In that is the essence of military-technical policy at the present stage.[147]

Since the mid-1960s (at least) the Soviet military press has shown great concern about the formulation and execution of military-technical policy, and has expressed a growing interest in new approaches to policy-making and management. This interest marks a response to the new pressures and demands on the Ministry of Defense and the General Staff, for it is they who, together with the appropriate planning agencies, devise military-technical policy; they act, it has been said, as "a sort of legislator" in this field.[148]

The writings about defense decision-making and management illustrate three main concerns. The first is anxiety about the cost of the defense effort. The party leadership has been willing to accord defense first priority, but has been conscious that this imposes a heavy burden on the rest of the economy. In 1963 Khrushchev declared that

> because the production of defense industries enterprises is secret, shortcomings in the work of such enterprises is closed to criticism ... Defense industry is coping successfully with creating and producing modern weapons. But these tasks could have been carried out more successfully and at a lower cost.[149]

The appointment of Ustinov as Minister of Defense this year may (in part) have reflected concern about the burden of defense spending. In any event it seems unlikely that the military press would have shown its recent interest in the economics of defense unless constrained to do so by political and economic pressure.

The interest in defense economics is closely related to the second major area of concern: the problem of weapons selection and force planning. The selection of designs for development and of models for production has been made more difficult by scientific progress and the complexity of technological choice. Since the early 1960s there appears to have been a growing emphasis on incorporating costing into the military decision-making process and using cost-effectiveness as a criterion of selection. This appears to apply both at the level of individual development project, and at the more general level of force planning. Thus, defense economics began to receive new attention in the military academies in the 1960s; and Cherednichenko has proposed the introduction of what is in effect a full-dress PPBS into defense policy-making.[150]

The third concern is that, in spite of its relatively successful operation, the military "research-production cycle" is not flexible enough to cope with present requirements. One military writer has commented that "the search for a more flexible organizational structure for research establishments is one of the ways of raising the effectiveness of scientific research in the interests of the country's defense."[151] Another has pointed to the need for closer links between the Navy and research institutes and design bureaus in industry.[152] Two other military writers have argued that "organic unity" between the Armed Forces, project-technological bureaus and enterprises is "a necessary condition for the really effective solution of the tasks of supplying the Armed Forces with modern combat materiel."[153] Sokolov has written that technological progress requires constant improvements in "the form and method of coordinating the activities of the armed forces and the national economy in the interests of the unity and flexibility of the system of economic support for the defense of the socialist states."[154]

There appear to be two specific anxieties here. The first is that scientific opportunities and military requirements will not coalesce quickly enough to ensure the development of the most advanced weapons. This is an important problem because rapid technological innovation lies at the heart of the East-West arms race. It is also a difficult problem because it requires flexibility and ease of communication in a political system dominated by departmental barriers and secrecy of information. The second anxiety is that the Ministry of Defense is not wholly successful in welding together the institutions in the "research-production cycle." There appear to be structural tensions between the Ministry and the defense industry. Orders placed by the Ministry have sometimes ignored the interests of the industrial managers, and have upset production schedules, called for frequent changes in production and interfered with plan fulfillment.[155]

The problems of decision-making and management are made clear not only in the writings on new approaches, but also in Soviet reflections on the disaster of 1941 and its causes. Two examples may be cited here. The first is that there are a number of cases where weapons which later proved extremely important met with military hostility or indifference. The Stalinist political process may have been effective in exercising power in support of priorities already decided upon; but the selection of specific programs as priorities of "state significance" was complex and hazardous. Radar development, for example, fell foul of disagreements between the artillery and air defense forces about their own requirements.[156] The potential of the "Katyusha" rocket artillery was not appreciated by the military at first.[157] The slow initial production of the T34 and KV tanks (the former now recognized as having been the best medium tank in the world at the time) was, at least in part, a consequence of the lack of military support.[158] According to Yakovlev, early in the War Stalin frequently reproached the military with lack of initiative and creative thinking in military technology.[159] This shows how great a responsibility their dominant position in the "research-production cycle" lays on the Armed Forces.

A second lesson to be drawn from the pre-war years is the need to coordinate military development with military production, and to plan carefully the whole assortment of military output, in particular the balance between old and new weapons. Thus Grechko:

> Before the last war the procurement of new models of military equipment proceeded slowly. Thus, right up to the beginning of the War we did not succeed, as we should have, in expanding the production of automatic rifles, and the army's requirement was only thirty per cent satisfied. In spite of the continuous growth of output of ammunition in the prewar years, industry on the eve of the War did not meet the army's requirement fully. By the middle of 1941 our aviation industry was only being restructured, its production base expanded, and preparation made for the series production of new, completely modern aircraft. By the beginning of the War only 20 per cent of the "park" of combat aircraft were new machines. The rest were

> obsolete, and moreover, of various different types which made them more complicated to operate. Tanks of new design, which were significantly superior in quality to the German tanks, were being turned out as yet in limited quantity, and by the summer of 1941 we had only about 9 per cent of them. The numerous other machines which the mechanized corps had were of obsolete types, of the most varied brands. This had very negative consequences in the ensuing events, in spite of the fact that we were superior to the Wehrmacht in quality of aircraft and tanks."[160]

The problem of obtaining the right balance between different types of military production evidently remains.

The new decision-making and management approaches might indeed go some way towards meeting the anxieties of the military and political leadership. Economic calculation and the introduction of some kind of program or output-budgeting might help to make the defense effort more efficient. Scientific-technological forecasting could improve the process of weapons selection, in particular in the earliest stage when technological possibility is married to military requirement. Network analysis and quality control techniques might give the Ministry of Defense and the Military-Industrial Commission more effective and flexible control over development and production programs. The systems approach which is much advocated might provide better cooperation and balance in military-technical policy as a whole.[161] But considerable problems would remain. There is no guarantee that economic calculation on the basis of existing prices would lead to any real increase in efficiency.[162] Moreover, the pursuit of efficiency by the Ministry of Defense might merely mean trying to ensure that the R&D establishment and the defense industrial enterprises bore as much of the cost as possible. An efficiency-conscious Ministry of Defense would not necessarily place a smaller military burden on the economy.

Conclusion

This paper has tried to sketch the institutional framework of the military "research-production cycle," and to outline the military role in managing technological innovation. It has tried also to show how the operation of the cycle has adapted to the emergence of a new relationship between science and military affairs. As was pointed out in the introduction, some very important issues have been omitted, and some aspects of the problems discussed have been given scant treatment, as for example: the effects of secrecy and the security agencies on the processes of innovation; the role of economic calculus in military R&D decision-making; changes in the style of decision-making over the last forty years; the working of the priority system; and the effect of new management approaches on power relationships.[163]

This paper has looked at the development of the institutional framework of the military R&D system over the last forty years, in the belief that this approach makes the best use of the available material.

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But one crucial element in the development of these institutions has received little emphasis: military competition with foreign powers. For most of the last forty years the Soviet Union has been caught up in an arms race - at first with Japan and Germany; after the War, with the United States and Western Europe; more recently, rivalry with China has come to the fore. Military competition with technologically more advanced powers has placed constant demands on the defense sector to produce new weapons. The drive "to catch up and overtake" has been very powerful in the military field. The fact that the Soviet leadership has most nearly achieved its "historic mission" in this field has not led to a diminution of effort; it has rather reinforced the commitment to military-technological progress, for fear that relaxation may lead to falling behind.

Military rivalry with technologically more advanced states (which has been such a marked feature of Russian and Soviet history) has had an important influence on the Soviet military R&D effort. The Soviet Union has drawn considerably on foreign science and technology, not only in the form of imported weapons (mainly in the 1930s and 1940s), but also in the form of design concepts, and more generally in basic and applied scientific reserach. A second consequence of the rivalry has been that the political leadership and the Armed Forces have made major efforts to extract resources from the economy and the society to meet what they saw as the needs of this competition.[164] The relative effectiveness of the military "research-production cycle" can be explained in terms of the powerful demands made upon it by the political and military leaders. It is their requirements that the cycle has to meet, and it is the management by the Soviet Armed Forces, backed by pressure from the political leadership, that has overcome, to a greater or lesser extent, the obstacles to innovation that are to be found elsewhere in the economy. The two elements of military management and political pressure are closely interwoven, for military-political consultation is crucial in defining military requirements, and military management is effective because it is underpinned by both political support and pressure.

This is not to say, however, that the dynamic of Soviet military R&D is to be explained only in terms of the competition with other states. The effort to ensure military-technological progress has created bureaucratic and political interests which have come to play a part in determining the course of that progress; it may be, indeed, that the Soviet effort is (to a greater or lesser extent) driven by an internal dynamic, created in the course of international rivalry but rooted now in the domestic power structure. Although the Soviet Armed Forces enjoy a special position in being able to impose their wishes on the production process, the structure of the defense sector itself gives a particular pattern to military output. Economic constraints and the internal arrangements of the sector affect the design and development of weapons: they foster commonality, simplicity and evolutionary design; they also encourage redundancy in development and production. This means, in general terms, that although particular military requirements may spring from international military rivalry, the way in which the requirements are met will be given a specific character by the institutional arrangements of the defense sector.

The defense industry and its R&D establishments impose a particular pattern on military output, but the analysis in this paper does not suggest that they generate rapid technological innovation. The pressure for innovation comes from two main internal sources: the Armed Forces and the political leadership, which make demands on defense production, and "civilian" institutions (especially the U.S.S.R. Academy of Sciences), which have provided the basis for new technologies with military applications. In the defense industry itself, two self-sustaining mechanisms can perhaps be identified: an action-reaction mechanism whereby the development of one weapon automatically triggers the search for a counter to it; and a "follow-on" mechanism whereby work more or less automatically begins on the design of a new generation of any weapon. In a sense it is the objective of the Armed Forces to make these internal mechanisms innovative by pressing military requirements and by grasping new technological possibilities.

Besides these general conclusions, three final points can be made. First, what differentiates the military "research-production cycle" from its civilian counterpart in the Soviet Union is the demands made on it, the resources made available to it, and the control exercised over it. These conditions cannot, however, be reproduced throughout the economy, for they depend on the peculiarly powerful position of the Armed Forces within the power structure, and hence on their power as customer; and on the granting of high priority to defense, and hence of low priority elsewhere. Secondly, this analysis gives particular importance to the Armed Forces in explaining the dynamic of military-technological progress. This implies, of course, a strong commitment to such progress on their part. Such a commitment - which certainly seems to exist - cannot be taken as unproblematic, however, especially in view of past failures. It remains, therefore, something to be analyzed and explained, and not merely taken for granted.

Thirdly, as military-technological progress has come to depend more on basic research, the distinction between civilian and military has blurred and new problems of management and decision-making have arisen. The system of weapons acquisition whose basic features were created in the 1930s has had to be adapted, and elements outside the defense sector (narrowly defined) integrated into the military "research-production cycle." The blurring of the civilian/military distinction is reflected in institutional arrangements. Although there are secret military R&D establishments, much military R&D is done in the establishments that are visible to us; consequently it is wrong to assume the existence of two separate R&D networks. In view of the new problems of management and decision-making in military R&D, it seems likely that the role of science policy agencies has grown for the defense effort, not in the sense of managing the military "research-production cycle" (where they may never have had any responsibility), but in servicing the needs of the defense sector.

Footnotes

[1]See, for example, Robert Mikulak, A Second Look at U.S. and Soviet Research and Development, Center for International Studies, MIT, February 1971; Resources Devoted to Military Research and Development, Stockholm International Peace Research Institute, 1972; World Armaments and Disarmament SIPRI Yearbook 1974, Stockholm, 1974 pp. 172-204; N. Nimitz, The Structure of Soviet Outlays on R&D in 1960 and 1968, R-1207-DDRE, Rand Corporation, Santa Monica, 1974; W. T. Lee, "Soviet Defense Expenditures," in W. Schneider Jr. and F. P. Hoeber (eds.), Arms, Men and Military Budgets, New York, 1976.

[2]In particular by Nimitz, op. cit.; and also by M. Agursky, The Research Institute of Machine-Building Technology, The Hebrew University of Jerusalem, The Soviet and East European Research Centre, Soviet Institutions Paper No. 8, September 1976.

[3]L. Trotsky, The Revolution Betrayed, Faber & Faber, London, 1937, p. 198.

[4]At the November Plenary Session of the Central Committee; quoted by A. Korol, Soviet Research and Development: Its Organization, Personnel and Funds, Cambridge, Mass. 1965, pp. 343-44.

[5]Materialy XXIV ogo s"yezda KPSS, Moscow, 1971, p. 46. This theme was taken up by military writers; see, for example, Major-General M. Cherednichenko in Kommunist vooruzhennykh sil, 1971, No. 18, p. 28.

[6]A. C. Sutton, Western Technology and Soviet Economic Development 1945-1965, Stanford, California, 1973, p. 361.

[7]See, for example, R. Perry, Comparisons of Soviet and U.S. Technology, R-827-PR, Rand Corporation, Santa Monica, 1973, p. 35; N. Nimitz, The Structure of Soviet Outlays on R&D in 1960 and 1968, R-1207-DDRE, Rand Corporation, Santa Monica, 1974, pp. vi, viii.

[8]See Perry, op. cit.; Congressional Record, Extensions of Remarks, August 4, 1971, pp. E8955-E8963; A. J. Alexander and J. R. Nelson, Measuring Technological Change: Aircraft Turbine Engines, R-1017-ARPA/PR, Rand Corporation, Santa Monica, 1972; N. D. Brodeur, Comparative Capabilities of Soviet and Western Weapon Systems, in M. MccGwire, K. Booth, and J. McDonnell (eds.), Soviet Naval Policy: Objectives and Constraints, New York, 1975, pp. 452-468. I have discussed the methodological problems, and made two case studies of Soviet weapons development (medium tanks and ICBMs) in a chapter in R. Amann, J. M. Cooper and R. W. Davies (eds.), The Technological Level of Soviet Industry, Yale UP, 1977.

[9]F. A. Long, in B. T. Feld et. al. (eds.), Impact of New Technologies on the Arms Race, Cambridge, Mass., 1971, p. 278; see also M. Leitenberg, International Social Science Journal, 1973, No. 3.

[10]For example, see N. A. Lomov et. al. (eds.), Nauchno-tekhnicheskii progress i revolutsiaya v voennom dele, Moscow, 1973.

[11]Lomov, op. cit., p. 29.

[12]Ibid. This paper does not look at the effects of technological change on "military work" or on the officer corps; I have touched on some aspects of this question in my Management, Technology and the Soviet Military Establishment, Adelphi Paper no. 76, ISS, London, 1971.

[13]M. Cherednichenko, "Ekonomika i voenno-tekhnicheskaya politika," Kommunist Vooruzhennykh Sil, 1968, No. 15, p. 13.

[14]V. Bondarenko, "Nauchno-tekhnicheskii progress i ukreplenie oboronosposobnosti strany," Kommunist Vooruzhennykh Sil, 1971, No. 24, p. 15.

[15]See M. Gallagher and K. Spielmann Jr., Soviet Decision-Making for Defense, New York, ch. 2.

[16]Informally, of course, Stalin dominated policy-making, and the niceties of jurisdiction and responsibility were ignored.

[17]"O sozdanii voenno-promyshlennoi komissii pri Komitete Oborony," KPSS o vooruzhennykh silakh Sovetskogo Soyuza, Moscow, 1969, p. 278.

[18]50 let Vooruzhennykh Sil SSSR, Moscow, 1968, p. 199.

[19]G. K. Zhukov, Vospominaniya i razmyshleniya, Moscow, 1969, p. 209.

[20]K. Meretskov, Serving the People, Moscow, 1971, p. 95.

[21]KPSS o vooruzhennykh silakh Sovetskogo Soyuza, p. 302.

[22]50 let ..., pp. 256, 267.

[23]50 let ..., p. 477.

[24]Yu. P. Petrov, Stroitel'stvo politorganov, partiinykh i komsomol'skikh organizatsii armii i flota (1918-1968), Moscow, 1968, p. 391.

[25]50 let ..., p. 478; thus A. V. Khrulyev, Deputy Minister of

Defense for the Rear, ceased to be a member of the higher Military Council in 1950. See Bol'shaya Sovetskaya Entsiklopedia, 2nd ed., vol 46, p. 387.

[26] See Petrov, op. cit., p. 507; V. I. Lenin i Sovetskie Vooruzhennye Sily, Moscow, 1967, p. 148.

[27] Yu. P. Petrov mentions the Higher Military Council in connection with Marshal Zhukov's dismissal from political life in 1957; see his Partiinoe stroitel'stovo v sovetskoi armii i flote, Moscow, 1964, p. 462. References to a Supreme Military Council in 1960 and 1961 may be found in The Penkovsky Papers, Fontana Books, 1967, pp. 140-41.

[28] Sovetskaya Voennaya Entsikolpedia, vol. 1, Moscow, 1976, p. 588.

[29] John Newhouse, Cold Dawn. The Story of SALT, New York, 1973, p. 251.

[30] M. Zakharov, "Kommunisticheskaya partiya i tekhnicheskoe perevooruzheniye armii i flota v gody predvoennykh pyatiletok," Voennoistoricheskii zhurnal, 1971, No. 2, p. 3.

[31] Julian Cooper, Defense Production and the Soviet Economy 1929-1941, CREES Discussion Paper, University of Birmingham, 1976, p. 6.

[32] Istoriya vtoroi mirovoi voiny 1939-45, vol. 2., Moscow, 1974, p. 188.

[33] Cooper, op. cit., pp. 7, 26-7.

[34] Cooper, op. cit., p. 39.

[35] V. A. Anfilov, Bessmertnyi Podvig, Moscow, 1971, p. 95.

[36] Istoriya kommunisticheskoi partii Sovetskogo Soyuza, vol. 5, book 1 (1938-45), Moscow, 1970, pp. 283-4.

[37] Ibid., p. 276; V. Kravchenko, I Chose Freedom, London, 1947, p. 404.

[38] Istoriya kommunisticheskoi partii Sovetskogo Soyuza, vol. 5, book 1, (1938-45), pp. 281-309; 436-473; A. M. Belikov, "Gosudarstvennyi Komitet Oborony i problemy sozdaniya slozhennoi voennoi ekonomiki," Sovetskii Tyl v velikoi otechestvennoi voine, vol 1, Moscow, 1974, pp. 70-79.

[39] E. Yu. Lokshin, Promyshlennost' SSSR 1940-63, Moscow, 1964, pp. 108-9.

[40] Lokshin, op. cit., pp. 110-112; Ekonomicheskaya Zhizn' SSSR, book 1, 1917-1950, Moscow, 1967, pp. 391-92.

[41] A. Yakovlev, Tsel' Zhizni, 4th ed., Moscow, 1974, p. 420.

[42] Lokshin, op. cit., pp. 112-113.

[43] Ibid., p. 113.

[44] Ibid., p. 122.

[45] Ekonomicheskaya Zhizn' SSSR, book 2, 1951-65, Moscow, 1967, pp. 459, 462, 473.

[46] Ibid., pp. 461, 470; Andrew Sheren, "Structure and Organization of Defense-Related Industries," Economic Performance and the Military Burden in the Soviet Union, A Compendium of Papers Submitted to the Subcommittee on Foreign Policy of the Joint Economic Committee, U.S. Congress, Washington, D.C., 1970, p. 130.

[47] Ekonomicheskaya Zhizn' SSSR, book 2, (1951-1965), Moscow, 1967, p. 486; Sheren, loc. cit., p. 130; that the Ministry of General Machine-Building produced conventional weapons in 1955-57 is suggested by the fact that P. N. Goremykin, the Minister, had been People's Commissar of Ammunition in 1941-42.

[48] John McDonnell, "The Soviet Defense Industry as a Pressure Group," M. MccGwire, K. Booth, and J. McDonnell (eds.), Soviet Naval Policy. Objectives and Constraints, New York, 1975, p. 90; the degree to which operational control of the enterprises passed to the sovnarkhozy seems problematic in view of the fact that central control of R&D was retained. Of course, the defense industry plants would have to have been tied into the sovnarkhoz system in some way for planning and supply purposes.

[49] See Korol, op. cit., pp. 45-49.

[50] Ekonomicheskaya Zhizn' SSSR, book 2, 1951-1965, Moscow, 1967, pp. 825, 654, 740.

[51] Sheren, loc. cit., p. 130; Michael Agursky, The Research Institute of Machine-Building Technology, The Hebrew University of Jerusalem, The Soviet and East European Research Centre, Soviet Institutions Series Paper No. 8, September 1976, p. 31. According to Agursky, the Ministry of General Machine-Building has a Technical Administration and four production glavki: for the production of ground equipment; for the production of rocket motors; for the production of control instruments; for the production and assembly of missiles. In the history of Soviet missile development Chief Designers have existed for these four areas; Korolyev was leader of the Council of Chief

Designers. See B. V. Raushenbakh, Yu. V. Biryukov, S. P. Korolyev - osnovopolozhnik prakticheskoi kosmonavtiki, Trudy XIII mezhdunarodnogo kongressa po istorii nauki, Sektsiya XII, Moscow 1974, p. 150.

52 Sheren, loc. cit., p. 130; Agursky, op. cit., p. 6.

53 Materialy XXIV s"yezda KPSS, Moscow 1971, p. 46.

54 Agursky, op. cit., p. 7.

55 Beria retained control of the nuclear weapons and missile programs. By the mid-1950s, Party Leaders seem to have had general rather than specific responsibility for the defense industry; thus from June 1957 (to May 1960?) Brezhnev was the Central Committee Secretary who concerned himself with heavy industry and "the construction, development and production of the newest military equipment and weapons and their supply to the Soviet Armed Forces, and the development of cosmonautics;" see Sovetskaya Voennaya Entsiklopedia, vol. 1, Moscow, 1976, p. 587.

56 Army General V. Tolubko, "Osnova boevogo mogushchestva," Tekhnika i vooruzheniye, 1974, No. 11, p. 3.

57 M. Tatu, Power in the Kremlin, London, 1969, p. 344. Agursky, op. cit., p. 5, names V. N. Novikov as head of the Military-Industrial Committee before 1970; perhaps there are two committees?

58 Cooper, op. cit., p. 24.

59 L. M. Ol'shchevits, N. A. Orlov, (eds.), Organizatsiya, planirovaniye i ekonomika aviatsionnogo proizvodstva, Moscow, 1963, p. 70.

60 N. Nimitz, op. cit., p. 44.

61 G. S. Kravchenko, Ekonomika SSSR v gody Velikoi Otechestvennoi voiny, Moscow, 1970, p. 85.

62 Agursky, op. cit., p. 33.

63 See Agursky, op. cit., p. 6.

64 Istoriya vtoroi mirovoi voiny 1939-45, vol. 1, Moscow, 1973, p. 257; Agursky, op. cit., p. 12; H. Smith, The Russians, London, 1976, p. 227.

65 Agursky, op. cit., pp. 21-22, 28-29; Smith, op. cit., p. 236; Cooper, op. cit., p. 3.

66 Agursky, op. cit., pp. 20-31.

[67] P. V. Sokolov, ed., Voenno-ekonomicheskie voprosy v kurse politekonomii, Moscow, 1968, p. 229.

[68] Agursky, op. cit., pp. 33-34.

[69] The defense industry is only one part of the "military economy" which includes transport, etc; moreover, the defense industry is conceived of in terms of a core (or cadre) and a reserve defense industry which could be turned rapidly to military production if the need arose. In the nuclear age the possibility of industrial mobilization during war has been much reduced, but it seems nevertheless to remain an important element in Soviet military-economic planning. See, for example, Sokolov, op. cit., pp. 209-17.

[70] Thus R. Tsvylev has argued that Soviet successes in space exploration, in the atomic and chemical industries and in aircraft development "have been to a great extent determined not only by the talent of the designers themselves, but also by the fact that design bureaus acted as the head, coordinating organ which disposed of resources freely for the solution of tasks set by the state. The departmental interests of the cooperating bodies were here superseded by the interests of achieving the goal set by the state." Voprosy Ekonomiki, 1971, No. 7, p. 73.

[71] E. Zaleski et. al., Science Policy in the U.S.S.R., Paris, 1969, p. 404; Nimitz, op. cit., pp. 7-14; A. J. Alexander, R&D in Soviet Aviation, R-589-PR, 1970, Rand Corporation, Santa Monica.

[72] See J. Milsom, Russian Tanks 1900-70, London, 1970, p. 41; V. D. Mostovenko, Tanki, Moscow, 1958, p. 115; Sotsialisticheskaya Industriya, 11 and 12 February, 1975; V. G. Grabin, "Oruzhie pobedy." Oktyabr', 1973, No. 10, p. 122.

[73] See S. Breyer, Guide to the Soviet Navy, Annapolis, 1970, ch. 3; J. W. Kehoe Jr., in U.S. Naval Institute Proceedings, August 1975.

[74] See Alexander, op. cit.; Yakovlev, op. cit.; L. L. Kerber, Tu - Chelovek i Samolet, Moscow 1973 for discussion of the work of aviation design bureaus.

[75] Agursky, op. cit., p. 11; Aviation Week and Space Technology, 2 July 1973, report on the Tu-144. This arrangement does not seem to have existed before the war; it was perhaps introduced during 1957-65 when the design bureaus remained under central control although the plants were nominally transferred to the sovnarkhozy. Agursky comments that in military design and development the psychological atmosphere is quite different from that in civilian industry becuase it is only here that the enthusiasm and passion of the Soviet system are felt; op. cit., p. 13.

[76] Agursky, op. cit., pp. 33-34.

[77] See Alexander, op. cit., pp. 11-16.

[78] Alexander, op. cit., pp. 17-28; Kehoe, loc. cit.; Congressional Record, loc. cit., p. E8962; M. MccGwire, "The Turning Points in Soviet Naval Policy," in MccGwire (ed.), Soviet Naval Developments. Capability and Contest, New York, 1973, pp. 176-209.

[79] AWST, October 11, 1976, p. 15.

[80] D. M. Berkovich et. al., (eds.), Ocherki razvitiya tekhniki v SSSR. Mashinostroenie. Avtomaticheskoe upravlenie mashinami i sistemami mashin. Radiotekhnika, elektronika i elektrosvyaz'. Moscow, 1970, pp. 349-351; Sovetskaya Voennaya Entsiklopedia, vol. 1, Moscow, 1976, p. 444.

[81] V. D. Skugarev, "Povyshat' effektivnost' nauchnyka issledovanii," Morskoi Sbornik, 1967, No. 1, p. 24. The Academy of Artillery Sciences, which existed from 1947 to 1953 and was one of the main efforts to establish a military scientific center, had four main tasks: to develop the theory of armament and of combat application of artillery; to make expert assessment of new models of armament; to prepare a history of artillery; and to train scientific cadres. Sovetskaya Voennaya Entsiklopedia, vol. 1, Moscow, 1976, pp. 130-31.

[82] B. V. Levshin, Akademiya nauk SSSR v gody velikoi otechestvennoi voiny, Moscow, 1966, p. 34.

[83] G. D. Komkov et. al., Akademiya nauk SSSR, Moscow, 1974, p. 353.

[84] Levshin, op. cit., pp. 39-61.

[85] Levshin, op. cit., p. 22; Zaleski et. al., op. cit., p. 198.

[86] Levshin, op. cit., p. 150.

[87] Komkov et. al., p. 390.

[88] I. N. Golovin, I. V. Kurchatov, 2nd ed., Moscow, 1973, p. 55; Zaleski et. al., op. cit., p. 227; (the date of transfer was perhaps 1963).

[89] Zaleski et. al., op. cit., p. 227. The Institute of Radio-engineering and Electronics set up in the Academy in 1951 may have started life in 1944 under the GKO's Council on Radar; see I. Radunskaya, Aksel' Berg - chelovek XX veka, Moscow 1971, p. 211; also I. V. Brenev, A. I. Bergu, "75 let," Izvestiya vuzov SSSR - radioelektronika, 1968, No. 10, pp. 1113-20.

[90] Zaleski et. al., op. cit., p. 207ff.

[91] For example, the Institute of Cybernetics of the Ukrainian Academy of Sciences, and the Institute of Control Problems; Entsiklopedia Kibernetiki, vol. 2, Kiev 1974, pp. 140-41.

[92] S. Kassel, The Relationship between Science and the Military in the Soviet Union, R-1457-DDRE/ARPA, 1974, Rand Corporation, Santa Monica, pp. 12-24; see also Berfovich et. al., op. cit., pp. 412-415.

[93] Agursky, op. cit., p. 5, writes that the Academy of Sciences and nearly all research institutes, universities and educational establishments have "closed" military programs and military and military-industrial research topics.

[94] V. D. Sokolovskii, Voennaya strategiya, 3rd ed., Moscow, 1968, p. 378.

[95] For example, the 1940 decision to give the Aviation Industry seven factories from other branches of industry; Istoriya KPSS, vol. 5, book 1 (1938-45), Moscow, 1970, p. 118.

[96] Sokolovskii, op. cit., p. 378.

[97] Zakharov, loc. cit., pp. 3-4; Istoriya vtoroi mirovoi voiny 1939-45, vol. 1, Moscow, 1973, pp. 257-58; the guidelines laid down initially were: (i) not to yield to probable enemies in the number of troops in the main theatre of war; (2) to attain superiority over the enemy in the decisive forms of armament - aviation, artillery and tanks.

[98] E. L. Warner III gives a similar account in "The Bureaucratic Politics of Weapons Procurement," in M. MccGwire, K. Booth, and J. McDonnell (eds.), Soviet Naval Policy. Objectives and Constraints. New York, 1975, pp. 70-71.

[99] Sokolov, op. cit., pp. 286-87.

[100] Sheren, loc. cit., p. 124.

[101] V. M. Ryabikov, holder of nine Orders of Lenin, and a former deputy Minister of Armament, was First Deputy Chairman of Gosplan from 1961 to 1974, where he may have had responsibility for the defense industry. See Pravda, 22 July 1974.

[102] Zakharov, loc. cit., p. 4; 50 let ..., gives July 1929 as the date when the post was set up (see appendix).

[103] See Marshal Biryuzov's introduction to M. N. Tukhachevskii, Izbrannye proizvedeniya, vol. 1, Moscow, 1964, p. 13ff.

[104] Zakharov, loc. cit., p. 4.

[105] Ibid.

[106] 50 let ..., p. 235.

[107] Bol'shaya Sovetskaya Entsiklopedia, 3rd ed., vol. 17, col. 1198; Sovetskaya Voennaya Entsiklopedia, vol. 1, pp. 145, 444.

[108] For Nedelin see BSE, 3rd ed., vol. 17, col. 1198. Yakovlev held the post from 1948. See Pravda, 12 June 1972, and Prominent Personalities in the U.S.S.R., New York, 1968.

[109] Sovetskaya Voennaya Entsiklopedia, vol. 1, p. 145.

[110] Boevoi Put' Sovetskogo Voenno-Morskogo Flota, 2nd ed., Moscow, 1974, p. 533; U.S.S.R. Strategic Survey: A Bibliography, Washington, D.C., 1969, p. 196; R. Kilmarx, A History of Soviet Air Power, New York, 1962, p. 113.

[111] See Yakovlev, op. cit., pp. 501-07; M. Gallagher and K. F. Spielman Jr., Soviet Decision-Making for Defense, New York, 1972, p. 20, Alexander, op. cit., p. 17ff.

[112] Agursky, op cit., p. 8; Agursky does not mention nuclear protection, but it is such a pervasive feature of Soviet weapons design that it might be written in at this stage.

[113] Zhukov, op. cit., pp. 206-207.

[114] Agursky, op. cit., pp.8-9.

[115] Various memoirs have made clear Stalin's detailed intervention in weapons development decisions; Zhukov (op. cit., p. 307) comments that "without Stalin's approval ... not one model of armament or combat materiel was taken into the arsenal or removed from it. Of course, this restricted the initiative of the Defense Commissar and his deputies who dealt with questions of the Red Army's armament." Khrushchev's role is not so clear, though he did not hesitate to express his views about the obsolescence of tanks and surface warships. Approval for all major programs is evidently still required, but it seems unlikely that the Party leaders still make detailed intervention in design decisions.

[116] Agursky, op. cit., p. 11.

[117] F. P. Avramchuk and S. A. Bartenev, "Ekonomicheskoe obosnovanie voennotekhnicheskoi politiki," Morskoi Sbornik, 1969, No. 2, p. 25.

[118] Zakharov, loc. cit., p.8.

[119] Sheren, loc. cit., p. 126.

[120] Agursky, op. cit., p. 9.

[121] Smith, op. cit., p. 236; Cooper, op. cit., p. 3.

[122] Agursky, op. cit., pp. 9-10.

[123] Zaleski et. al., op. cit., pp. 564-65.

[124] Istoriya vtoroi mirovoi voiny 1939-45, vol. 2, Moscow, 1974, pp. 188-9.

[125] Ibid.

[126] Levshin, op. cit., p. 34.

[127] G. S. Kravchenko, op. cit., p.205.

[128] Berkovich et. al., eds., op. cit., p. 374; Radunskaya, op. cit., p. 205.

[129] Levshin, op. cit., p.36.

[130] Tolubko, loc. cit., p. 3.

[131] Yakovlev, op. cit., pp. 420-21.

[132] Korol, op. cit., pp. 337-38.

[133] See Golovin, op. cit., p. 68; R. W. Herrick, Soviet Naval Strategy, Annapolis, 1968, pp. 63-64.

[134] Korol, op. cit., p. 337; the first annual plan for the introduction of new technology was approved in 1949; see Zaleski et. al., op. cit., p. 75.

[135] Quoted by McDonnell, loc. cit., p. 92.

[136] Ibid.; Alekseev, the present Deputy Minister of Defense for Armament, was working in the Council of Ministers from 1955-58 (see note 109 above), which might suggest the existence of a special military R&D or military-industrial body at that time.

[137] Kassel, op. cit., pp. 34-37.

[138] Although Maksarev, its head, was an associate of Malyshev's and had been director of plant No. 183 which produced tanks during the War.

[139] XXI s"yezd KPSS. Stenograficheskii Otchet, vol. 2, Moscow, 1962, pp. 275-82.

[140] Korol, op. cit., pp. 325-335; Zaleski et. al., op. cit., pp. 56-57.

[141] Zaleski, et. al., op. cit., p. 57ff; Kassel, op. cit., pp. 4-11.

[142] Robert Adamson, "Mobilizing Soviet Science," Scientific Research, 22 January 1968, p. 25.

[143] Kassel, op. cit., pp. 38-40.

[144] Gallagher and Spielmann, op. cit., p. 20; these bodies figure prominently in the history of weapons development, but little is known of their present activities. It is interesting to note, however, that the Technical Committee of the Joint Armed Forces of the Warsaw Pact (Tekhnicheskii komitet Ob"yedinennykh Vooruzhennykh Sil) concerns itself with the development and improvement of armament and equipment, "with coordination of the efforts of the allied armies in the sphere of R&D (NIOKR).... In recent years the Technical Committee has carried out highly significant work in coordinating R&D connected with the equipping of the allied armies with armament and materiel, and this has had great economic results. Thanks to the coordinated work of the Technical Committee and of the organs in charge of armament and equipment, the armies of the member states of the Warsaw Pact are at the present time succeeding in solving in the most effective way the problems of creating equipment and armaments, and all other questions connected with this. The work of the Technical Committee is carried out in close contact with the corresponding national organs." (I. I. Yakubovskii, ed.), Boevoe sodruzhestvo bratskikh narodov i armii, Moscow, 1975, p. 146). This (ambiguous) passage seems to imply an important military role in the management of R&D; would the "corresponding national organ" in the Soviet Union be the General Staff's Scientific-Technical Committee?

[145] A. A. Grechko, Vooruzhennye Sily Sovetskogo Gosudarstva, 2nd ed., Moscow 1975, p. 193; "Military-technical policy" has been defined as "the system of measures which support and direct the activity of developing, producing and assimilating military equipment in accordance with the demands of the objective laws of war and the task of achieving maximum combat effectiveness at minimum cost;" Avramchuk and Bartenev, loc. cit., pp. 24-25.

[146] Grechko, op. cit., pp. 193-94.

[147] M. Cherednichenko, "Ekonomika i Voenno-tekhniceskaya politika," Kommunist Vooruzhennykh Sil, 1968, No. 15, p. 9.

[148] Avramchuk and Bartenev, loc. cit., p. 25.

[149]Quoted in Hearings before the Subcommittee on Economy in Government of the Joint Economic Committee, Congress of the United States, Part 3, The Economic Basis of the Russian Military Challenge to the United States, June 23 and 24, 1969, Washington, D.C., p. 963.

[150]See Yu. Vlas'evich, "Voenno-ekonomicheskie voprosy v kurse politekonomii," Kommunist Vooruzhennykh Sil, 1968, No. 22, p. 89-92; I. Prokhorenko, "Ekonomicheskaya podgotovka voennykh inzhererov," Kommunist Vooruzhennykh Sil, 1966, No.5, pp. 47-51; M. Cherednichenko, "Sovremennaya voina i ekonomika," Kommunist Vooruzhennykh Sil, 1971, No. 18, pp. 25-27.

[151]V. Bondarenko, "Nauchno-tekhnicheskii progress i ukreplenie oboronosposobnosti strany," Kommunist Vooruzhennykh Sil, 1971, No. 24, p. 16.

[152]Skugarov, loc. cit., p. 25.

[153]Avramchuk and Bartonev, loc. cit., p. 25.

[154]Sokolov, op. cit., p. 287.

[155]As in civilian industry, so in military production: the enterprise has an interest in long, undisturbed production runs.

[156]See J. Erickson, "Radio-location and the Air Defense Problem: The Design and Development of Soviet Radar 1934-40," Science Studies, 1972, No. 2, pp. 241-68.

[157]Zhukov, op. cit., pp. 213-14.

[158]I. Krupchenko, "Marshal bronetankovykh voisk Ya. N. Fedorenko," Voennoistoricheskii zhurnal, 1966, No. 10, p. 48.

[159]A. S. Yakovlev, Tsel' Zhizui, 2nd ed., Moscow, 1968, p. 502.

[160]A. Grechko, "25 let tomu nazad," Voenno-istoricheskii zhurnal, 1966, No. 6, pp. 8-9.

[161]See Grechko, op. cit., p. 193; Yu. S. Solnyshkov, Optimizatsiya vybora vooruzheniya, Moscow, 1968.

[162]I have not examined here the thorny problem of prices; Sokolov (op. cit., pp. 226-27) points out that a uniform level of wholesale prices is needed if the "real outlays of society on the defense of the country" are to be established and compared with other outlays. The implication seems to be that such uniformity does not exist; see also M. Checinski, "The Costs of Armament Production and the Profitability of Armament Exports in COMECON Countries," Osteuropa Wirtschaft, 1975, No. 2,

p. 134.

163 I have explored some of these issues in Management, Technology and the Soviet Military Establishment, Adelphi Paper No. 76, ISS, London, 1971, and in "Technology and Political Decision in Soviet Armaments Policy," Journal of Peace Research, 1974, No. 4, pp. 257-279.

164 See A. C. Sutton, Western Technology and Soviet Economic Development 1930-1945, and Western Technology and Soviet Economic Development, 1945-1965, Stanford, California, 1971 and 1973.

TABLE 2

The Soviet Defense Industry

1	Ministry of Defense Industry	-	conventional weapons
2	Ministry of Aviation Industry	-	aircraft and aircraft parts
3	Ministry of Shipbuilding Industry	-	ships
4	Ministry of Electronics Industry	-	electronic components and equipment
5	Ministry of Radio Industry	-	
6	Ministry of Medium Machine-Building	-	nuclear weapons
7	Ministry of General Machine-Building	-	strategic missiles
8	Ministry of Machine-Building	-	ammunition

Sources:

Andrew Sheren, "Structure and Organization of Defense-Related Industries," Economic Performance and the Military Burden in the Soviet Union, A Compendium of Papers Submitted to the Subcommittee on Foreign Economic Policy of the Joint Economic Committee, U.S. Congress, Washington, D.C., 1970, pp. 123-132; Michael Agursky, The Research Institute of Machine-Building Technology, The Hebrew University of Jerusalem, The Soviet and East European Research Centre, Soviet Institutions Series Paper No. 8, September 1976, p. 6.

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ROUTING AND RECORD SHEET

SUBJECT: (Optional) DCI Discussion/Dinner on Soviet Science and Technology Lags, Wednesday, 18 October 1978

STAT

FROM: [redacted] Coordinator for Academic Relations, NFAC

Jack

EXTENSION: [redacted]

NO. NFAC No. 4432/78

STAT

DATE 11 October 1978

TO: (Officer designation, room number, and building)	DATE RECEIVED	DATE FORWARDED	OFFICER'S INITIALS	COMMENTS (Number each comment to show from whom to whom. Draw a line across column after each comment.)
1. [redacted]				Charlie: This is the Director's copy of the invitation to the insiders who are to attend the Dinner/Discussion on next Wednesday, with the reading materials attached. Please pass it to him when he will have a chance to review the attachments if he wishes. [redacted]
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